JOURNAL AND PROCEEDINGS

OF THE

ROYAL SOCIETY

OF

NEW SOUTH WALES.

EDITED BY

THE HONORARY SECRETARIES.

THE AUTHORS OF PAPERS ARE ALONE RESPONSIBLE FOR THE OPINIONS EXPRESSED THEREIN.

PUBLISHED BY THE SOCIETY, 5 ELIZABETH STREET NORTH, SYDNEY.
LONDON AGENTS:
GEORGE ROBERTSON & Co., PROPRIETARY LIMITED,
17 WARWICK SQUARE, PATERNOSTER ROW, LONDON, E.C.

1904.

CONTENTS.

VOLUME XXXVII.

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OF THE

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OF

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FOR

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(INCORPORATED 1881.)

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NOTICE.

The Royal Society of New South Wales originated in 1821 as the "Philosophical Society of Australasia"; after an interval of inactivity, it was resuscitated in 1850, under the name of the "Australian Philosophical Society," by which title it was known until 1856, when the name was changed to the "Philosophical Society of New South Wales"; in 1866, by the sanction of Her Most Gracious Majesty the Queen, it assumed its present title, and was incorporated by Act of the Parliament of New South Wales in 1881.

TO AUTHORS.

Authors of papers desiring illustrations are advised to consult the editors (Honorary Secretaries) before preparing their drawings. Unless otherwise specially permitted, such drawings should be carefully executed to a large scale on smooth white Bristol board in intensely black Indian ink, so as to admit of the blocks being prepared directly therefrom, in a form suitable for photographic "process." The size of a full page plate in the Journal is 4¼ in. × 6¾ in. The cost of all original drawings, and of colouring plates must be borne by Authors.

ERRATA.

Page 329, last line, for "boxolanose," read "*borolanose.*"
 „ 336, line 9, for "andesite," read "*andesine.*"
 „ 337, line 9 from bottom, for "Magnetite," read "*Magnetite and glass.*"
 „ 338, line 11, for "layer," read "*larger.*"
 „ 341, for "S_1O_2," read "SiO_2."
 „ 341, column IV. (item 10) for "2·30," read "1·18."
 „ 345, line 3 from bottom, for "Bue," read "Blue."
Plate 26, for "Fig. 3," read "Fig. 4."
 „ 26, for "Fig. 4," read "Fig. 3."

PUBLICATIONS.

Transactions of the Philosophical Society, N.S.W., 1862-5, pp. 374, out of print.

Vol.	I.	Transactions of the Royal Society, N.S.W.,	1867,	pp. 83,	„
„	II.	„ „ „ „ „	1868,	„ 120,	„
„	III.	„ „ „ „ „	1869,	„ 173,	„
„	IV.	„ „ „ „ „	1870,	„ 106,	„
„	V.	„ „ „ „ „	1871,	„ 72,	„
„	VI.	„ „ „ „ „	1872,	„ 123,	„
„	VII.	„ „ „ „ „	1873,	„ 182,	„
„	VIII.	„ „ „ „ „	1874,	„ 116,	„
„	IX.	„ „ „ „ „	1875,	„ 235,	„
„	X.	Journal and Proceedings „ „	1876,	„ 333,	„
„	XI.	„ „ „ „ „	1877,	„ 305,	„
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„	XXXVII.	„ „ „ „ „	1903,	„ 663,	„ 10s. 6d.

CONTENTS.

VOLUME XXXVII.

Royal Society of New South Wales.

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I bequeath the sum of £   to the ROYAL SOCIETY OF NEW SOUTH WALES, Incorporated by Act of the Parliament of New South Wales in 1881, and I declare that the receipt of the Treasurer for the time being of the said Corporation shall be an effectual discharge for the said Bequest, which I direct to be paid within   calendar months after my decease, without any reduction whatsoever, whether on account of Legacy Duty thereon or otherwise, out of such part of my estate as may be lawfully applied for that purpose.

[*Those persons who feel disposed to benefit the Royal Society of New South Wales by Legacies, are recommended to instruct their Solicitors to adopt the above Form of Bequest.*]

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Members are particularly requested to communicate any change of address to the Hon. Secretaries, for which purpose this slip is inserted.

Corrected Address:

Name ....

....

Titles, &c ....

....

Address ....

....

....

Date..........................

To the
Hon. Secretaries,
The Royal Society of N. S. Wales,
5 Elizabeth Street, Sydney.

LIST OF THE MEMBERS

OF THE

Royal Society of New South Wales.

P Members who have contributed papers which have been published in the Society's Transactions or Journal; papers published in the Transactions of the Philosophical Society are also included. The numerals indicate the number of such contributions.

‡ Life Members.

Elected.		
1877	P 5	Abbott, W. E., 'Abbotsford,' Wingen.
1895		Adams, J. H. M., Broughton Cottage, St. James' Rd., Waverley.
1890	P 2	Allan, Percy, M. Inst. C.E., Assoc. M. Am. Soc. C.E., Engineer-in-Charge of Bridge Design, Public Works Department, Sydney.
1885		Allworth, Joseph Witter, Chief Surveyor, Lands Department, Sydney.
1898		Alexander, Frank Lee, c/o Messrs. Goodlet and Smith Ld., Cement Works, Granville.
1902		Ames, William (late R.N.) M. Inst. N.A., Fleet Engineer (Reserve List) Commonwealth Naval Forces, 'Chelmsford,' West-street, North Sydney.
1877		Anderson, H. C. L., M.A., Principal Librarian, Public Library of N. S. Wales, 161 Macquarie-street.
1903		Arnott, Arthur James, A.M.I.C.E., M.I.M.E., M.I.E.E., Electrical Engineer, 83 Pitt-street.
1902		Arnott, John M , 'Strathfield,' Strathfield.
1899	P 1	Atkinson, A. A., Chief Inspector of Collieries, Department of Mines, Sydney.
1878		Backhouse, Alfred P., M.A., District Court Judge, 'Melita,' Elizabeth Bay.
1894	P 8	Baker, Richard Thomas, F.L.S., Curator, Technological Museum.
1900		Bale, Ernest, C.E., Public Works Department.
1894		‡Balsille, George, 'Sandymount,' Dunedin, New Zealand.
1895	P 6	Bancroft, T. L., M.B. *Edin.*, Deception Bay, viâ Burpengary, Brisbane, Queensland.
1896		Barff, H. E., M.A., Registrar, Sydney University.
1895	P 8	Barraclough, S. H., B.E., M.M.E., Assoc. M. Inst. C.E., Memb. Soc. Promotion Eng. Education, Lecturer in Mechanism and Applied Thermodynamics, Sydney University; p.r. 'Marmion,' Victoria-street, Lewisham.
1901		Bartholomew, Charles P., 361 George-street.
1903		Bayly, Francis William, Assayer, Royal Mint, Sydney.
1894		Baxter, William Howe, Chief Surveyor Existing Lines Office, Railway Department, Bridge-street.
1877		Belfield, Algernon H., 'Eversleigh,' Dumaresq.
1876		Benbow, Clement A., 48 College-street.
1900		Bender, Ferdinand, Accountant and Auditor, 21 Elizabeth-street, North.

Elected		
1869	P 2	Bensusan, S. L., Equitable Building, George-st., Box 411 G.P.O.
1901		Birks, Lawrence, B.Sc., Assoc. M. Inst. C.E., A.M.I.E.E., F.G.S., City Electrical Engineer. Christchurch, New Zealand.
1888		‡Blaxland, Walter, F.R.C.S. *Eng.*, L.R.C.P. *Lond.*, Mount Barker, South Australia.
1893		Blomfield, Charles E., B.C.E. *Melb.*, Public Works Department, Sydney.
1898		Blunno, Michele, Licentiate in Science (Rome), Government Viticultural Expert, Department of Agriculture, Sydney.
1879		‡Bond, Albert, 131 Bell's Chambers, Pitt-street.
1891		Bowman, Archer S., B.E., 'Keadue,' Elizabeth Bay Road.
1893		Bowman, John Assoc. M. Inst. C.E., Tramway Construction Branch, Public Works Department.
1876		Brady, Andrew John, Lic. K. & Q. Coll. Phys. *Irel.*, Lic. R. Coll. Sur. *Irel.*, 3 Lyons' Terrace, Hyde Park.
1891		Brennand, Henry J. W., B.A., M.B., Ch. M. Syd. Univ., F.R.A.S., F.C.S., 231 Macquarie-street.
1902		Brereton, Victor Le Gay, Solicitor, Tattersall's Chambers, Hunter-st.; p.r. 'Osgathorpe,' Gladesville.
1878		‡Brooks, Joseph, F.R.A.S., F.R.G.S., 'Hope Bank,' Nelson-street, Woollahra.
1876		Brown, Henry Joseph, Solicitor, Newcastle.
1891		Bruce, John Leck, Technical College, Sydney.
1903		Bruck, Ludwig, Medical Publisher, 15 Castlereagh-street.
1898		Burfitt, W. Fitzmaurice, B.A., B.Sc., M.B., Ch.M. *Syd.*, 311 Glebe Road, Glebe Point.
1891	P 6	Burge, Charles Ormsby, M. Inst. C.E., 'Fitz Johns,' Alfred-street, N., North Sydney.
1890		Burne, Dr. Alfred, Dentist, 1 Lyons' Terrace, Liverpool.street.
1880		Bush, Thomas James, M. Inst. C.E., Engineer's Office, Australian Gas-Light Company, 163 Kent-street.
1876		Cadell, Alfred, Coramba, viâ South Grafton.
1902		Calder, Robert A., Dentist, 87 Phillip-street.
1899		Cameron, R. B., Secretary A.M.P. Society, 87 Pitt-street.
1900		Canty, M., 'Rosemont,' 13 York-street, Wynyard Square.
1876		Cape, Alfred J., M.A. *Syd.*, 'Karoola,' Edgecliffe Rd., Edgecliffe.
1897	P 3	Cardew, John Haydon, Assoc. M. Inst. C.E., L.S., 75 Pitt-street.
1901		Card, George William, A.R.S.M., F.G.S., Curator and Mineralogist to the Geological Survey. N.S.W. Department of Mines.
1891		Carment, David, F.I.A. *Grt. Brit. & Irel.*, F.F.A. *Scot.*, Australian Mutual Provident Society, 87 Pitt-st. *Hon. Treasurer.*
1903		Carslaw, H. S., M.A., D.Sc., Professor of Mathematics, Sydney University, Glebe.
1879	P 1	‡Chard, J. S., Licensed Surveyor, Armidale.
1878		Chisholm, Edwin, M.R.C.S. *Eng.*, L.S.A. *Lond.*, Roslyn Gardens, Rushcutters Bay.
1885		Chisholm, William, M.D. *Lond.*, 139 Macquarie-street, North.
1896	P 1	Cook, W. E., M.C.E. *Melb.* Univ., M. Inst. C.E., District Engineer, Water ond Sewerage Department, North Sydney.
1903		Cooper, David John, M.A., Superintendent Technical Education, Technical College.
1876		Codrington, John Frederick, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, L.R.C.P. *Edin.*, 'Wynwood,' Wahroonga.

Elected		
1893		Cohen, Algernon A., M.B., M.D. *Aberd.*, M.R.C.S. *Eng.*, 61 Darlinghurst Road.
1876		Colyer, J. U. C., 'Malvern,' Collingwood and Seymour-streets, Drummoyne.
1882		Cornwell, Samuel, Australian Brewery, Bourke-st., Waterloo.
1891		Coutie, W. H., M.B., Ch.B., Univ. *Melb.*, 'Warminster,' Canterbury Road, Petersham.
1892	P 1	Cowdery, George R., Assoc. M. Inst. C.E., Engineer for Tramways, Phillip-street; p.r. 'Glencoe,' Torrington Rd., Strathfield.
1886		Crago, W. H., M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, 16 College-street, Hyde Park.
1869		Creed, The Hon. J. Mildred, M.L.C., M.R.C.S. *Eng.*, L.R.C.P. *Edin.*, 195 Elizabeth-street.
1870		Croudace, Thomas, Lambton.
1891	P 5	Curran, Rev. J. Milne, Lecturer in Geology, Technical College, Sydney.
1875		Dangar, Fred. H., c/o Messrs. Dangar, Gedye, & Co., Mercantile Bank Chambers, Margaret-street.
1890		Dare, Henry Harvey, M.E., Assoc. M. Inst. C.E., Roads and Bridges Branch, Public Works Department.
1876	P 3	Darley, Cecil West, M. Inst. C.E., 34 Campden Hill Court, Campden Hill Road, Kensington, London, W.
1877		Darley, The Hon. Sir Frederick, G.C.M.G., B.A., Chief Justice, Supreme Court.
1886	P 17	David, T. W. Edgeworth, B.A., F.G.S., F.R.S., Professor of Geology and Physical Geography, Sydney University, Glebe.
1892	P 1	Davis, Joseph, M. Inst. C.E., Under Secretary, Department of Public Works.
1878		Dean, Alexander, J.P., 42 Castlereagh-street, Box 409 G.P.O.
1885	P 2	Deane, Henry, M.A., M. Inst. C.E., Engineer-in-Chief for Railways, Railway Construction Branch, Public Works Department; p.r. 'Blanerne,' Wybalena Road, Hunter's Hill.
1877		Deck, John Feild, M.D. Univ. *St. Andrews*, L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, 203 Macquarie-st.; p.r. 92 Elizabeth-st., Ashfield.
1899	P 1	De Coque, J. V., Public Works Department, Sydney.
1894		Dick, James Adam, B.A. *Syd.*, M.D., C.M. *Edin.*, 'Catfoss,' Belmore Road, Randwick.
1875	P 12	Dixon, W. A., F.C.S., Fellow of the Institute of Chemistry of Great Britain and Ireland, 97 Pitt-street.
1880		Dixson, Thomas, M.B. *Edin.*, Mast. Surg. *Edin.*, 287 Elizabeth-street, Hyde Park.
1876		Docker, Ernest B., M.A. *Syd.*, District Court Judge, 'Eltham,' Edgecliffe Road.
1899		Duckworth, A., A.M.P. Society, 87 Pitt-st.; p.r. 'Trentham,' Woollahra,
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1877		‡Fairfax, Edward Ross, *S. M. Herald* Office, Hunter-street.
1896		Fairfax, Geoffrey E., *S. M. Herald* Office, Hunter-street.
1868		Fairfax, Sir James R., Knt., *S. M. Herald* Office, Hunter-st.
1887		Faithfull, R. L., M.D. *New York* (Coll. Phys. & Surg.) L.R.C.P., L.S.A. *Lond.*, 18 Wylde-street.
1902		Faithfull, William Percy, Barrister-at-Law, Australian Club.
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1881		Foster, The Hon. W. J., K.C., 'Thurnby,' 35 Enmore Road, Newtown.
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1881		Furber, T. F., Trignometrical Survey; p.r. 'Tennyson House,' 145 Victoria-street.
1899		Garran, R. R., M.A., C.M.G., Commonwealth Offices, Spring-st., Melbourne.
1876		George, W. R., 318 George-street.
1869		Gerard, Francis, 'The Grange,' Monteagle, near Young.
1896		Gibson, Frederick William, District Court Judge, 'Grasmere,' Stanmore Road.
1891		Gill, Robert J,, Public Works Department, Tumberumba.
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1859		Goodlet, J. H., 'Canterbury House,' Ashfield.
1896		Gollin, Walter J., Australian Club.
1897		Gould, Major The Hon. Albert John, Senator, 'Eynesbury,' Edgecliffe.
1886		Graham, Sir James, Knt., M.A., M.D., M.B., C.M. *Edin.*, 188 Liverpool-street.
1891	P 1	Grimshaw, James Walter, M. Inst. C.E., M. I. Mech. E., &c., Australian Club.
1899	P 1	Gummow, Frank M., M.C.E., Assoc. M. Inst. C.E., Vickery's Chambers, 82 Pitt-street.
1891	P 8	Guthrie, Frederick B., F.I.C., F.C.S., Department of Agriculture, 136 George-street, Sydney. *President.*
1900		Hadley, Arthur, F.C.S., Standard Brewery, Sydney.
1880	P 2	Halligan, Gerald H., F.G.S., 'Riversleigh,' Hunter's Hill.
1899		Halloran, Aubrey, B.A., LL.B., 20 Castlereagh-street.
1892		Halloran, Henry Ferdinand, L.S., Scott's Chambers, 94 Pitt-st.

Elected		
1887	P 7	Hamlet, William M., F.I.C., F.C.S., Member of the Society of Public Analysts; Government Analyst, Health Department, Macquarie-street North. *Vice-President.*
1881		‡Harris, John, 'Bulwarra,' Jones-street, Ultimo.
1877	P 18	‡Hargrave, Lawrence, J.P., Woollahra Point.
1884	P 1	Haswell, William Aitcheson, M.A., D.Sc., F.R.S., Professor of Zoology and Comparative Anatomy, University, Sydney; p.r. 'Mimihau,' Woollahra Point.
1899		Hawker, Herbert.
1900		Hawkins, W. E., Solicitor, 88 Pitt-street.
1890	P 2	Haycroft, James Isaac, M.E. Queen's Univ. *Irel.*, Assoc. M. Inst. C.E., Assoc. M. Can. Soc. C.E., Assoc. M. Am. Soc. C.E., M.M. & C.E., M. Inst. C.E.I., L.S., 'The Grove,' off Queen-street, Woollahra.
1891	P 1	Hedley, Charles, F.L.S., Assistant in Zoology, Australian Museum, Sydney,
1900	P 2	Helms, Richard, Experimentalist, Department of Agriculture.
1902		Hennessy, John Francis, Architect, Ashpitel Prizeman and Silver Medallist, Royal Institute of British Architects, City Chambers, 243 Pitt-street.
1899		Henderson, J., Manager, City Bank of Sydney, Pitt-street.
1899		Henderson, S., M.A., Assoc. M. Inst. C.E., Equitable Building, George-street.
1884		Henson, Joshua B., Assoc. M. Inst. C.E., Hunter District Water Supply and Sewerage Board, Newcastle.
1876	P 2	Hirst, George D., F.R.A.S., 379 George-street.
1896		Hinder, Henry Critchley, M.B., C.M. *Syd.*, Elizabeth-st., Ashfield.
1892		Hodgson, Charles George, 157 Macquarie-street.
1901		Holt, Thomas S., 'Holwood,' Victoria-street, Ashfield.
1891	P 2	Houghton, Thos. Harry, M. Inst. C.E., M. I. Mech. E., 63 Pitt-street.
1879		Houison, Andrew, B.A., M.B., C.M. *Edin*, 47 Phillip-street.
1877		Hume, J. K., 'Beulah,' Campbelltown.
1894	P 2	Hunt, Henry A., F.R. Met. Soc., First Meteorological Assistant, Sydney Observatory.
1903		Irvine, R. F., M A., Examiner for Public Service Board; p.r. Musgrave-street, Mosman.
1891		Jamieson, Sydney, B A., M.B., M.R.C.S., L.R.C.P., 189 Liverpool-street, Hyde Park.
1900		Jarman, Arthur, A.R.S.M., Demonstrator, University of Sydney.
1903		Jenkinson, Edward H., M. I. Mech. E., 15 Macquarie Place.
1902		Jevons, Stanley, B.A. *Cantab.*, B.Sc. *Lond.*, Sydney University, Glebe.
1903		Johnston, J. Barre-, 20 Loftus-street, p.r. Mosman.
1902		Jones, Henry L., Assoc. M. Am. Soc. C.E., 14 Martin Place.
1884		‡Jones, Llewellyn Charles Russell, Solicitor, Sydney Chambers, 130 Pitt-street.
1867		Jones, P. Sydney, M.D. *Lond.*, F.R.C.S. *Eng.*, 16 College-street, Hyde Park; p.r. 'Llandilo,' Boulevard, Strathfield.
1876		Jones, Richard Theophilus, M.D. *Syd.*, L.R.C.P. *Edin.*, 'Cader Idris,' Ashfield.
1876	P 2	Josephson, J. Percy, Assoc. M. Inst. C.E., Stephen Court, 81 Elizabeth-street; p.r. 'Moppity,' George-street, Dulwich Hill.
1878		Joubert, Numa, Hunter's Hill.

Elected		
1883		Kater, The Hon. H. E., J.P., M.L.C., Australian Club.
1873		Keele, Thomas William, M. Inst. C.E., President, Metropolitan Board of Water Supply and Sewerage, 341 Pitt-street.
1877		Keep, John, Broughton Hall, Leichhardt.
1887		Kent, Harry C., M.A., Bell's Chambers, 129 Pitt-street.
1903		Kennedy, Thomas, Assoc. M. Inst. C.E., Railway Construction Branch, Public Works Department.
1901		Kidd, Hector, Assoc. M. Inst. C.E., 'Craig Lea,' 15 Mansfield-street, Glebe Point.
1891		King, Christopher Watkins, Assoc. M. Inst. C.E., L.S., Assistant Engineer, Harbours and Rivers Department, Newcastle.
1874		King, The Hon. Philip G., M.L.C., 'Banksia,' William-street, Double Bay.
1896		King, Kelso, 120 Pitt-street.
1892		Kirkcaldie, David, Commissioner, New South Wales Government Railways, Sydney.
1878		Knaggs, Samuel T., M.D. *Aberdeen*, F.R.C.S. *Irel.*, 5 Lyons' Terrace, Hyde Park.
1881	P 17	Knibbs, G. H., F.R.A.S., Lecturer in Surveying, University of Sydney; p.r. 'Spottiswoode,' 28 Bland-st., Ashfield. *Hon. Secretary.*
1877		Knox, Edward W., 'Rona,' Bellevue Hill, Double Bay.
1878		Kyngdon, F. B., F.R.M.S. *Lond.*, Deanery Cottage, Bowral.
1874		Lenehan, Henry Alfred, F.R.A.S., Sydney Observatory.
1901		Lindeman, Charles F., Wine Merchant, Jersey Rd., Strathfield.
1883		Lingen, J. T., M.A. *Cantab.*, 167 Phillip-street.
1901		Little, Robert, 'The Hermitage,' Rose Bay.
1872	P 54	Liversidge, Archibald, M.A. *Cantab.*, LL.D., F.R.S., Hon. F.R.S. *Edin.*, Assoc. Roy. Sch. Mines, *Lond.*; F.C.S., F.G.S., F.R.G.S.; Fel. Inst. Chem. of Gt. Brit. and Irel.; Hon. Fel. Roy. Historical Soc. *Lond.*; Mem. Phy. Soc. *Lond.*; Mineralogical Society, *Lond.*; Edin. Geol. Soc.; Mineralogical Society, *France*; Corr. Mem. Edin. Geol. Soc.; New York Acad. of Sciences; Roy. Soc. *Tas.*; Roy. Soc., *Queensland*; Senckenberg Institute, *Frankfurt*; Société d' Acclimat., *Mauritius*; Foreign Corr. Indiana Acad. of Sciences; Hon. Mem. Roy. Soc. *Vict.*; N. Z. Institute; K. Leop. Carol. Acad., *Halle a/s*; Professor of Chemistry in the University of Sydney, The University, Glebe; p.r. 'The Octagon,' St. Mark's Road, Darling Point. *Vice President.*
1884		MacCormick, Alexander, M.D., C.M. *Edin.*, M.R.C.S. *Eng.*, 125 Macquarie-street, North.
1887		MacCulloch, Stanhope H., M.B., C.M. *Edin.*, 24 College-street.
1892		McDonagh, John M., B.A., M.D., M.R.C.P. *Lond.*, F.R.C.S. *Irel.*, 173 Macquarie-street, North.
1897		MacDonald, C. A., C.E., 68 Pitt-street.
1878		MacDonald, Ebenezer, J.P., c/o Perpetual Trustee Co. Ld., 2 Spring-street.
1868		MacDonnell, William J., F.R.A.S., 15 Post Office Chambers, Pitt-street.

Elected		
1903		McDonald, Robert, Commissioner, Western Land Board, Castlereagh-street.
1891		McDouall, Herbert Crichton, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, D.P.H. *Camb.*, Hospital for Insane, Callan Park, Rozelle.
1900		McKay, G. A., Federal Public Service Commissioner's Office, Macquarie-st.; p.r. 'Edgeroi,' Clifton Avenue, Burwood.
1891		McKay, R. T., C.E., 'Tranquilla,' West street, North Sydney.
1893		McKay, William J. Stewart, B.Sc., M.B., Ch.M., Cambridge-street, Stanmore.
1876		Mackellar, The Hon. Charles Kinnaird, M.L.C., M.B., C.M. *Glas.*, Equitable Building, George-street.
1876		Mackenzie, Rev. P. F., The Manse, Johnston-st., Annandale.
1880	P 9	McKinney, Hugh Giffin, M.E. Roy. Univ. *Irel.*, M. Inst. C. E., Exchange, 56 Pitt-street; p.r. 'Dilkhusha,' Fuller's Road, Chatswood.
1903		McLaughlin, John, Solicitor, Clement's Chambers, 88 Pitt-st.
1876		MacLaurin, The Hon. Sir Henry Normand, M.L.C., M.A., M.D. L.R.C.S. *Edin.*, LL.D. Univ. *St. Andrews*, 155 Macquarie-st.
1901	P 1	McMaster, Colin J., Chief Commissioner of Western Lands; p.r. 'Monomie,' Longueville.
1894		McMillan, Sir William, 'Logan Brae,' Waverley.
1900		MacTaggart, A. H., D.D.S. *Phil.* U.S.A., King and Phillip-sts.
1899		MacTaggart, J. N. C., B.E. *Syd.*, Water and Sewerage Board, 341 Pitt-street.
1882	P 1	Madsen, Hans F., 'Hesselmed House,' Queen-st., Newtown.
1883	P 13	Maiden, J. Henry, J.P., F.L.S., Hon. Fellow Roy. Soc., S.A.; Hon. Memb. Mueller Bot. Soc., W.A.; Netherlands Soc. for Promotion of Industry; Philadelphia Coll. Pharm.; Pharm. Soc. N.S.W.; Brit. Pharm. Conf.; Corr. Fellow Therapeutical Soc. Lond.; Corr. Memb. Pharm. Soc. Great Britain; Soc. Nac. de Agricultura (Chile); Soc. d' Horticulture d' Alger; Union Agricole Calédonienne; Soc. Nat. etc. de Chérbourg; Roy. Soc., Tas.; Government Botanist and Director, Botanic Gardens, Sydney. *Hon. Secretary.*
1880	P 1	Manfred, Edmund C., Montague-street, Goulburn.
1869		Mansfield, G. Allen, Martin Chambers, Moore-street.
1897		Marden, John, B.A., M.A., LL.B. Univ. *Melb.*, LL.D. Univ. *Syd.*, Principal, Presbyterian Ladies' College, Sydney.
1875	P 18	Mathews, Robert Hamilton, L.S., Assoc. Mem. Soc. d'Anthrop. de Paris; Cor. Mem. Anthrop. Soc., Washington, U.S.A.; Cor. Mem. Roy. Geog. Soc. Aust., Queensland, 'Carcuron,' Hassall-street, Parramatta.
1903		Meggitt, Loxley, Manager Co-operative Wholesale Society, Alexandria.
1896	P 5	Merfield, Charles J., F.R.A.S., Railway Construction Branch, Public Works Department; p.r. 'Branville,' Green Bank-street, Marrickville.
1887		Miles, George E., L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, The Hospital, Rydalmere, near Parramatta.
1903		Minell, W. Percy, Incorporated Accountant, Martin Chambers, Moore-street.

Elected		
1889	P 8	Mingaye, John C. H., F.I.C., F.C.S., Assayer and Analyst to the Department of Mines, Government Metallurgical Works, Clyde; p.r. Campbell-street, Parramatta.
1856	P 7	Moore, Charles, F.R.B.S., C.M.Z.S., Australian Club; p.r. 6 Queen-street, Woollahra.
1879		Moore, Frederick H., Illawarra Coal Co., Gresham-street.
1875		Moir, James, 58 Margaret-street.
1877		‡Mullens, Josiah, F.R.G.S., 'Tenilba,' Burwood.
1879		Mullins, John Francis Lane, M.A. *Syd.*, 'Killountan,' Challis Avenue, Pott's Point.
1887		Munro, William John, B.A., M.B., C.M., M.D. *Edin.*, M.R.C.S. *Eng.*, 213 Macquarie-street; p.r. 'Forest House,' 182 Pyrmont Bridge Road, Forest Lodge.
1876		Myles, Charles Henry, 'Dingadee,' Burwood.
1893		Nangle, James, Architect, Australia-street, Newtown.
1901		Newton, Roland G., 'Walcott,' Boyce-street, Glebe Point.
1891		‡Noble, Edwald George, 21 Norfolk-street, Paddington.
1873		Norton, The Hon. James, M.L.C., LL.D., Solicitor, 2 O'Connell-street; p.r. 'Ecclesbourne,' Double Bay.
1893		Noyes, Edward, C.E., c/o Messrs. Noyes Bros., 109 Pitt-street.
1903		Old, Richard, Solicitor, 'Waverton,' Bay Rd., North Sydney.
1896		Onslow, Lt. Col. James William Macarthur, Camden Park, Menangle.
1875		O'Reilly, W. W. J., M.D., M.Ch., Q. Univ. *Irel.*, M.R.C.S. *Eng.*, 197 Liverpool-street, Hyde Park,
1883		Osborne, Ben. M., J.P., 'Hopewood,' Bowral.
1891		Osborn, A. F., Assoc. M. Inst. C.E., Public Works Department, Cowra.
1903		Owen, Rev. Edward, B.A., All Saints' Rectory, Hunter's Hill.
1880		Palmer, Joseph, 96 Pitt-st.; p.r. Kenneth-st., Willoughby.
1878		Paterson, Hugh, 197 Liverpool-street, Hyde Park.
1901		Peake, Algernon, Assoc. M. Inst. C.E. 25 Prospect Road, Ashfield.
1899		Pearse, W., Union Club; p.r. Moss Vale.
1877		Pedley, Perceval R., 227 Macquarie-street.
1877		Perkins, Henry A., c/o Perpetual Trustee Co. Ld., 2 Spring-st.
1899		Peterson, T. Tyndall, Associate Sydney Institute of Public Accountants, Harold-street, Gordon.
1879	P 6	Pittman, Edward F., Assoc. R. S.M., L.S., Under Secretary and Government Geologist, Department of Mines.
1899		Plummer, John, 'Northwood,' Lane Cove River, Box 413 G.P.O.
1881		Poate, Frederick, Lands Office, Moree.
1879		Pockley, Thomas F. G., Commercial Bank, Singleton.
1887	P 1	Pollock, James Arthur, B.E. Roy. Univ. *Irel.*, B.Sc. *Syd.*, Professor of Physics, Sydney University.
1891		Poole, William, Junr., B.E. *Syd.*, Assoc. M. Inst. C.E., F.G.S., L.S., B. H. Proprietary Co. Ld., Port Pirie, South Australia; p.r. 87 Pitt-street, Redfern.

Elected		
1896		Pope, Roland James, B.A. *Syd.*, M.D., C.M., F.R.C.S. *Edin.*, Ophthalmic Surgeon, 235 Macquarie-street.
1897	P 1	Portus, A. B., Assoc. M. Inst. C.E., Superintendent of Dredges, Public Works Department.
1893		Purser, Cecil, B.A., M.B., Ch. M. *Syd.*, 'Valdemar,' Boulevard, Petersham.
1901	P 1	Purvis, J. G. S., Water and Sewerage Board, 341 Pitt-street.
1876		Quaife, F. H., M.A., M.D., Mast. Surg. *Glas.*, 'Hughenden,' 14 Queen-street, Woollahra.
1899	P 1	Rae, J. L. C., Manager Sydney Harbour Collieries Ltd.; p.r. 'Strathmore,' Ewenton-street, Balmain.
1900		Ralston, J. T., Solicitor, 86 Pitt-street.
1902		Ramsay, Arthur A., Assistant Chemist, Department of Agriculture, 136 George-street.
1865	P 1	‡Ramsay, Edward P., LL.D. Univ. St. And., F.R.S.E., F.L.S., 8 Palace-street, Petersham.
1901		Raymond, Robert S., Brewer, c/o Messrs. King & Co., Leichhardt
1890		Rennie, George E., B.A. *Syd.*, M.D. *Lond.*, M.R.C.S. *Eng.*, 40 College-street, Hyde Park.
1870		Renwick, The Hon. Sir Arthur, Knt., M.L.C., B.A. *Syd.*, M.D., F.R.C.S. *Edin.*, 295 Elizabeth-street.
1902		Richard, G. A., Mount Morgan Gold Mining Co., Mount Morgan, Queensland.
1903	P 1	Rooke, Thomas, A.M.I.C.E., Electrical Engineer, Town Hall, Sydney.
1893	P 1	Roberts, W. S. de Lisle, C.E., 170 Princes-street.
1885		Rolleston, John C., Assoc. M. Inst. C.E., Harbours and Rivers Branch, Public Works Department.
1897		Ronaldson, James Henry, Mining Engineer, 76 Pitt-street.
1892		Rossbach, William, Assoc. M. Inst. C.E., Chief Draftsman, Harbours and Rivers Branch, Public Works Department.
1884		Ross, Chisholm, M.D. *Syd.*, M.B., C.M. *Edin.*, 147 Macquarie-st.
1895		Ross, Colin John, B. Sc., B.E., Assoc. M. Inst. C.E., Borough Engineer, Town Hall, North Sydney.
1895	P 1	Ross, Herbert E., Consulting Engineer and Architect, Equitable Building, George-street.
1882		Rothe, W. H., Colonial Sugar Co., O'Connell-street, and Union Club.
1864	P 69	Russell, Henry C., B.A. *Syd.*, C.M.G., F.R.S., F.R.A.S., F. R. Met. Soc., Hon. Memb. Roy. Soc., South Australia, Government Astronomer, Sydney Observatory. *Vice-President.*
1897		Russell, Harry Ambrose, B.A., Solicitor, c/o Messrs. Sly and Russell, 379*b* George-street; p.r. 'Mahuru,' Milton-street, Ashfield.
1893		Rygate, Philip W., M.A., B.E., *Syd.*, Assoc. M. Inst. C.E., Phoenix Chambers, 158 Pitt-street.

Elected		
1899		Schmidlin, F., 83 Elizabeth-street, Sydney.
1892	P 1	Schofield, James Alexander, F.C.S., A.R.S.M., University, Sydney.
1856	P 1	‡Scott, Rev. William, M.A. *Cantab.*, Kurrajong Heights.
1903		Scott, William B., Principal, Homebush Grammar School, p.r. Albert Road, Strathfield.
1877	P 4	Selfe, Norman, M. Inst. C.E., M. I. Mech. E., Victoria Chambers, 279 George-street.
1891		Shaw, Percy William, Assoc. M. Inst. C.E., Resident Engineer for Tramway Construction; p.r. 'Epcombs,' Miller-street, North Sydney.
1883	P 3	Shellshear, Walter, M. Inst. C.E., Inspecting Engineer, Existing Lines Office, Bridge-street.
1900		Simpson, R. C., Technical College, Sydney.
1882		Sinclair, Eric, M.D., C.M. Univ. *Glas.*, Inspector-General of Insane, 9 Richmond Terrace, Domain, p r. Cleveland-st., Wahroonga.
1893		Sinclair, Russell, M. I. Mech. E., etc., Consulting Engineer, Vickery's Chambers, 82 Pitt-street.
1884		Skirving, Robert Scot, M.B., C.M. *Edin.*, Elizabeth-street, Hyde Park.
1891	P 2	Smail, J. M. M. Inst. C.E., Chief Engineer, Metropolitan Board of Water Supply and Sewerage, 341 Pitt-street.
1893	P 26	Smith, Henry G., F.C.S., Assistant Curator, Technological Museum, Sydney.
1874	P 1	‡Smith, John McGarvie, 89 Denison-street, Woollahra.
1899		Smith, R. Greig, D.Sc. *Edin.*, M.Sc. *Dun.*, Macleay Bacteriologist, 'Otterburn," Double Bay.
1886		Smith, Walter Alexander, M. Inst. C.E., Roads, Bridges and Sewerage Branch, Public Works Department; 12*a* Phillip-st.
1896		Smyth, Selwood, Harbours and Rivers Branch, Public Works Department.
1896		Spencer, Walter, M.D. *Brux.*, 13 Edgeware Road, Enmore.
1903		Stoddart, Rev. A. G., The Rectory, Manly.
1892	P 1	Statham, Edwyn Joseph, Assoc. M. Inst. C.E., Cumberland Heights, Parramatta.
1900		Stewart, J. D., M.R.C.V.S., Government Veterinary Surgeon, Department of Mines and Agriculture; p.r. Cowper-street, Randwick.
1883	P 3	Stuart, T. P. Anderson, M.D., LL.D. Univ. *Edin.*, Professor of Physiology, University of Sydney; p.r. 'Lincluden,' Fairfax Road, Double Bay.
1901		Süssmilch, C. A., Technical College, Sydney.
1893		‡Taylor, James, B. Sc., A.R.S.M., Adderton Road, Dundas.
1899		Teece, R., F.I.A., F.F.A., Actuary, A.M.P. Society, 87 Pitt-st.
1861	P 19	Tebbutt, John, F.R.A.S., Private Observatory, The Peninsula, Windsor, New South Wales.
1896		Thom, James Campbell, Solicitor, 'Dunoon,' Eurella-street, Burwood.
1896		Thom, John Stuart, Solicitor, Athenæum Chambers, 11 Castlereagh-street.
1878		Thomas, F. J., Hunter River N.S.N. Co., Sussex-street.
1879		Thomson, Dugald, M.H.R., 'Wyreepi,' Milson's Point.

Elected		
1885	P 2	Thompson, John Ashburton, M.D. *Brux.*, D.P.H. *Camb.*, M.R.C.S. *Eng.*, Health Department, Macquarie-street.
1896		Thompson, Capt. A. J. Onslow, Camden Park, Menangle.
1892		Thow, William, M. Inst. C.E., M.I. Mech. E., Locomotive Department, Eveleigh.
1888		Thring, Edward T., F.R.C.S. *Eng.*, L.R.C.P. *Lond.*, 225 Macquarie-street.
1894		Tidswell, Frank, M.B., M. Ch., D.P.H. *Camb.*, Health Department, Sydney.
1894		Tooth, Arthur W., Kent Brewery, 26 George-street, West.
1873	P 1	Trebeck, Prosper N., J.P., Cowle's Road, Mosman.
1879		Trebeck, P. C., F. R. Met. Soc., 12 O'Connell-street.
1900		Turner, Basil W., A.R.S M., F.C.S., Wood's Chambers, Moore-st.
1883		Vause, Arthur John, M.B., C.M.,*Edin.*, 'Bay View House,' Tempe.
1884		Verde, Capitaine Felice, Ing, Cav., viâ Fazio 2, Spezia, Italy.
1890		Vicars, James, M.C.E., M. Inst. C.E., City Surveyor, Adelaide.
1892		Vickery, George B., 78 Pitt-street.
1903		Vonwiller, Oscar U., B.Sc., Demonstrator in Physics, University of Sydney.
1876		Voss, Houlton H., J.P., c/o Perpetual Trustee Company Ld., 2 Spring-street.
1898	P 1	Wade, Leslie A. B., Assoc. M. Inst. C.E., Department of Public Works.
1879		Walker, H. O., Commercial Union Assurance Co., Pitt-street.
1899		‡Walker, Senator J. T., 'Rosemont,' Ocean-street, Woollahra.
1901		Walkom, A. J., A.M.I.E.E., Mem. Elec. Assoc. N.S.W., Electrical Branch, G.P.O. Sydney.
1900		Wallach, Bernhard, B.E. *Syd.*, Electrical Engineer, 'Oakwood,' Wardell Road, Dulwich Hill.
1891		Walsh, Henry Deane, B.E., T.C. *Dub.*, M. Inst. C.E., Engineer-in-Chief, Harbour Trust, Circular Quay.
1903		Walsh, Fred., 23 Elizabeth-st; p.r. 'Walworth,' Park Road, City E.
1901		Walton, R. H., F.C.S., 'Flinders,' Martin's Avenue, Bondi.
1898		Wark, William, 9 Macquarie Place; p.r. Kurrajong Heights.
1902		Warren, Ernest W., B.E., B.A. LL.B., Barrister-at.Law, No. 7, Wentworth Court, Phillip-street.
1877		Warren, William Edward, B.A., M D., M. Ch., Queen's University *Irel.*, M.D. *Syd.*, 283 Elizabeth-street, Sydney.
1883	P 14	Warren, W. H., Wh. Sc., M. Inst. C.E., Professor of Engineering, University of Sydney. *Vice-President.*
1876		Watkins, John Leo, B.A. *Cantab.*, M.A. *Syd.*, Parliamentary Draftsman, Attorney General's Department, Macquarie-st.
1876		Watson, C. Russell, M.R.C.S. *Eng.*, 'Woodbine,' Erskineville Road, Newtown.
1897		Webb, Fredk. William, C.M.G., J.P., 'Livadia,' Manly.
1903		Webb, A. C. F., Consulting Electrical Engineer, Vickery's Chambers, 82 Pitt-street.
1892		Webster, James Philip, Assoc. M. Inst. C.E., L.S., *New Zealand*, Town Hall, Sydney.

Elected		
1867		Weigall, Albert Bythesea, B.A. *Oxon.*, M.A. *Syd.*, Head Master, Sydney Grammar School, College-street.
1902		Welsh, David Arthur, Professor of Pathology, Sydney University, Glebe.
1881		‡Wesley, W. H.
1878		Westgarth, G. C., Bond-street; p.r. 52 Elizabeth Bay Road.
1879		‡Whitfeld, Lewis, M.A. *Syd.*, 'Glencoe,' Lower Forth-street, Woollahra.
1892		White, Harold Pogson, F.C.S., Assistant Assayer and Analyst, Department of Mines; p.r. 'Quantox,' Park Road, Auburn.
1877		‡White, Rev. W. Moore, A.M., LL.D., T.C.D.
1883		Wilkinson, W. Camac, M.D. *Lond.*, M.R.C.P. *Lond.*, M.R.C.S. *Eng.*, 213 Macquarie-street.
1876		Williams, Percy Edward, Comptroller, Government Savings Bank, Sydney.
1901		Willmot, Thomas, J.P., Toongabbie.
1878		Wilshire, James Thompson, F.L.S., F.R.H.S., J.P., 'Coolooli,' Bennet Road, Neutral Bay.
1879		Wilshire, F. R., P.M., Penrith.
1890		Wilson, James T., M.B., Mast. Surg. Univ. *Edin.*, Professor of Anatomy, University of Sydney.
1873		Wood, Harrie, J.P., 10 Bligh-street; p.r. 54 Darlinghurst Road.
1891		Wood, Percy Moore, L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, 'Redcliffe,' Liverpool Road, Ashfield.
1876	P 1	Woolrych, F. B. W., 'Verner,' Grosvenor-street, Croydon.
1902		Wright, John Robinson, Lecturer in Art, Technical College, Harris-street, Sydney.
1879		Young, John, 'Kentville,' Johnston-street, Leichhardt.

Honorary Members.

Limited to Thirty.

M.—Recipients of the Clarke Medal.

1901		Baker, Sir Benjamin, K.C.M.G., D.Sc., LL.D., F.R.S., etc., 2 Queen Square Place, London, S.W.
1875		Bernays, Lewis A., C.M.G., F.L.S., Brisbane.
1900		Crookes, Sir William, F.R.S., 7 Kensington Park Gardens, London W.
1875	M	Ellery, Robert L. J., F.R.S., F.R.A.S., c/o Government Astronomer of Victoria, Melbourne.
1887		Foster, Sir Michael, M.D., F.R.S., Professor of Physiology, University of Cambridge.
1875	M	Gregory, The Hon. Sir Augustus Charles, K.C.M.G., M.L.C., F.R.G.S. Brisbane.
1875	P 1 M	Hector, Sir James, K.C.M.G., M.D., F.R.S., late Director of the Colonial Museum and Geological Survey of New Zealand, Wellington, N.Z.
1880	M	Hooker, Sir Joseph Dalton, K.C.S.I., M.D., C.B., F.R.S., &c., c/o Director of the Royal Gardens, Kew.
1892		Huggins, Sir William, K.C.B., D.C.L., LL.D., F.R.S., &c., 90 Upper Tulse Hill, London, S.W.

Elected		
1888	P 1 M	Hutton, Captain Frederick Wollaston, F.G.S., Curator, Canterbury Museum, Christchurch, New Zealand.
1901		Judd, J. W., C.B., F.R.S., F.G.S., Professor of Geology, Royal College of Science, London.
1903		Kelvin, Right Hon. William Thomson, Lord, O.M., G.C.V.O., D.C.L., LL.D., F.R.S., etc., 15 Eaton Place, London, S.W.
1903		Lister, Right Hon. Joseph, Lord, O.M., B.A., M.B., F.R.C.S. D.C.L., F.R.S., etc., 12 Park Crescent, Portland Place, London, W.
1901		Newcomb, Professor Simon. LL.D., Ph. D., For. Mem. R.S. Lond., United States Navy, Washington.
1894		Spencer, W. Baldwin, M.A., Professor of Biology, University of Melbourne.
1900	M	Thiselton-Dyer, Sir William Turner, K.C.M.G., C.I.E., M.A., B.Sc. F.R.S., F.L.S., Director, Royal Gardens, Kew.
1895		Wallace, Alfred Russel, D.C.L. *Oxon.*, LL.D. *Dublin*, F.R.S., Broadstone, Wimborne, Dorset.

Obituary 1903.

Ordinary Members.

1891	Firth, T. R.
1876	Manning, Dr. F. Norton.
1882	Milson, James.
1877	Morris, Dr. W.
1876	Pickburn, Dr. Thomas.
1876	Toohey, Hon. J. T.

Obituary 1904.

Ordinary Member.

1878	Low, Hamilton Lambart

AWARDS OF THE CLARKE MEDAL.

Established in memory of

The late Revd. W. B. CLARKE, M.A., F.R.S., F.G.S., &c.,

Vice-President from 1866 *to* 1878.

To be awarded from time to time for meritorious contributions to the Geology, Mineralogy, or Natural History of Australia.

1878 Professor Sir Richard Owen. K.C.B., F.R.S., Hampton Court.

1879 George Bentham, C.M.G., F.R.S., The Royal Gardens, Kew.

1880 Professor Thos. Huxley, F.R.S., The Royal School of Mines, London. 4 Marlborough Place, Abbey Road, N.W.

1881 Professor F. M'Coy, F.R.S., F.G.S., The University of Melbourne.

1882 Professor James Dwight Dana, LL.D., Yale College, New Haven, Conn., United States of America.

1883 Baron Ferdinand von Mueller, K.C.M.G., M.D., PH.D., F.R.S., F.L.S., Government Botanist, Melbourne.

1884 Alfred R. C. Selwyn, LL.D., F.R.S., F.G.S., Director of the Geological Survey of Canada, Ottawa.

1885 Sir Joseph Dalton Hooker, K.C.S.I., C.B., M.D., D.C.L., LL.D., &c., late Director of the Royal Gardens, Kew.

1886 Professor L. G. De Koninck, M.D., University of Liège, Belgium.

1887 Sir James Hector, K.C.M.G., M.D., F.R.S., Director of the Geological Survey of New Zealand, Wellington, N.Z.

1888 Rev. Julian E. Tenison-Woods, F.G.S., F.L.S., Sydney.

1889 Robert Lewis John Ellery, F.R.S., F.R.A.S., Government Astronomer of Victoria, Melbourne.

1890 George Bennett, M.D. Univ. *Glas.*, F.R.C.S. *Eng.*, F.L.S., F.Z.S., William Street, Sydney.

1891 Captain Frederick Wollaston Hutton, F.R.S., F.G.S., Curator, Canterbury Museum, Christchurch, New Zealand.

1892 Sir William Turner Thiselton Dyer, K.C.M.G., C.I.E., M.A., B.Sc., F.R.S., F.L.S., Director, Royal Gardens, Kew.

1893 Professor Ralph Tate, F.L.S., F.G.S., University, Adelaide, S.A.

1895 Robert Logan Jack, F.G.S., F.R.G.S., Government Geologist, Brisbane, Queensland.

1895 Robert Etheridge, Junr., Government Palæontologist, Curator of the Australian Museum, Sydney.

1896 Hon. Augustus Charles Gregory, C.M.G., M.L.C., F.R.G.S., Brisbane.

1900 Sir John Murray, Challenger Lodge, Wardie, Edinburgh.

1901 Edward John Eyre, Walreddon Manor, Tavistock, Devon, England.

1902 F. Manson Bailey, F.L.S., Colonial Botanist of Queensland, Brisbane.

1903 Alfred William Howitt, F.G.S., Hon. Fellow Anthropol. Inst. of Gt. Britain and Ireland, 'Eastwood,' Bairnsdale, Victoria.

AWARDS OF THE SOCIETY'S MEDAL AND MONEY PRIZE.

The Royal Society of New South Wales offers its Medal and Money Prize for the best communication (provided it be of sufficient merit) containing the results of original research or observation upon various subjects published annually.

Money Prize of £25.

1882 John Fraser, B.A., West Maitland, for paper on 'The Aborigines of New South Wales.'

1882 Andrew Ross, M.D., Molong, for paper on the 'Influence of the Australian climate and pastures upon the growth of wool.'

The Society's Bronze Medal and £25.

1884 W. E. Abbott, Wingen, for paper on 'Water supply in the Interior of New South Wales.'

1886 S. H. Cox, F.G.S., F.C.S., Sydney, for paper on 'The Tin deposits of New South Wales.

1887 Jonathan Seaver, F.G.S., Sydney, for paper on 'Origin and mode of occurrence of gold-bearing veins and of the associated Minerals.

1888 Rev. J. E. Tenison-Woods, F.G.S., F.L.S., Sydney, for paper on 'The Anatomy and Life-history of Mollusca peculiar to Australia.'

1889 Thomas Whitelegge, F.R.M.S., Sydney, for 'List of the Marine and Fresh-water Invertebrate Fauna of Port Jackson and Neighbourhood.

1889 Rev. John Mathew, M.A., Coburg, Victoria, for paper on 'The Australian Aborigines.

1891 Rev. J. Milne Curran, F.G.S., Sydney, for paper on 'The Microscopic Structure of Australian Rocks.'

1892 Alexander G. Hamilton, Public School, Mount Kembla, for paper on 'The effect which settlement in Australia has produced upon Indigenous Vegetation.'

1894 J. V. De Coque, Sydney, for paper on the 'Timbers of New South Wales.'

1894 R. H. Mathews, L.S., Parramatta, for paper on 'The Aboriginal Rock Carvings and Paintings in New South Wales.'

1895 C. J. Martin, B.Sc., M.B. *Lond.*, Sydney, for paper on 'The physiological action of the venom of the Australian black snake (*Pseudechis porphyriacus*).'

1896 Rev. J. Milne Curran, Sydney, for paper on 'The occurrence of Precious Stones in New South Wales, with a description of the Deposits in which they are found.'

PRESIDENTIAL ADDRESS.

By Professor W. H. WARREN, Wh. Sc., M. Inst. C.E., M. Am. Soc. C.E.

[*Read before the Royal Society of N. S. Wales, May 6, 1903.*]

ROYAL SOCIETY OF NEW SOUTH WALES.

Financial Position.—The expenses incurred during the year have been rather heavier than usual, chiefly in regard to the cost of publishing the Journal and repairs to the premises; the Hon. Treasurer has however been able to pay his way and to carry forward a balance of £8 19s. 8d.

The Library.—The sum spent during the year upon books and periodicals was £92 5s. 7d., and upon binding £2 10s. 6d.

Exchanges.—Last year the Society exchanged its Journal and Proceedings with 426 kindred Institutions, the following having been added to the list:—Musée Nacional de Buenos Aires; Deutsches Meteorologisches Gesellschaft, Aachen; Instituto Geologico de Mexico; Naturforschende Gesellschaft, Basel; American Microscopical Society, Lincoln, Nebr.; and in return it has received 289 volumes, 1,511 parts, 136 reports, 174 pamphlets, 1 hydrographic and 2 meteorological charts, total 2,113.

Papers read in 1902.—During the past year the Society held eight (8) meetings at which 17 papers were read, the average attendance of members was 50 and of visitors 3.

I.—The Parks of Sydney; some of the problems of control and management. By J. H. Maiden, Director of Botanic Gardens and Domains, Sydney; Officer-in-Charge of the Centennial Park, [*With Plate.*]

II.—Possible relation between Sunspot Minima and Volcanic Eruptions. By H. I. Jensen, (Communicated by Prof. David, B.A., F.R.S. [*With Plate.*]

III.—Notes on two chemical constituents from the Eucalypts. By Henry G. Smith, F.C.S., Assistant Curator, Technological Museum.

IV.—The Aboriginal Languages of of Victoria. By R. H. Mathews, L.S., Memb. Assoc. Entran. Soc. d'Anthrop. de Paris.

V.—The Mitigation of Floods in the Hunter River. By J. H. Maiden.

VI.—A rapid Gravimetric Method of Estimating Lime. By F. B. Guthrie, F.I.C., F.C.S., and C. R. Barker.

VII.—Languages of some Native Tribes of Queensland, New South Wales and Victoria. By R. H. Mathews, L.S., Corres. Memb. Anthrop. Soc., Washington, U.S.A.

VIII.—Pot Experiments to determine the Limits of Endurance of different Farm-crops for certain injurious substances. By F. B. Guthrie, F.I.C., F.C.S., and R. Helms.

IX.—Current Papers, No. 7. By H. C. Russell, B.A., C.M.G., F.R.S. [*With Diagrams.*]

X.—Forests considered in their Relation to Rainfall and the Conservation of Moisture. By J. H. Maiden.

XI.—Meteoric Dusts, New South Wales. By Professor A. Liversidge, LL.D., F.R.S., University of Sydney.

XII.—Occurrence of Gadolinite in West Australia. By Bernard F. Davis, B.Sc.; with notes by W. G. Woolnough, B.Sc., F.G.S., and Prof. T. W. E. David, B.A., F.R.S.

XIII.—Investigation in regard to the comparative strength and elasticity of Portland Cement Mortar and Concrete when reinforced with Steel Rods and when not reinforced. By W. H. Warren, M. Inst. C.E., Wh. Sc., Challis Professor of Engineering, University of Sydney.

XIV.—The fallacy of assuming that a wet year in England will be followed by a wet year in Australia. By H. C. Russell, B.A., C.M.G., F.R.S. [*With Diagrams.*]

XV.—Is Eucalyptus Variable? By J. H. Maiden, Director, Botanic Gardens, Sydney, Government Botanist of New South Wales.

XVI.—The Boogaldi, Barratta Nos. 2 and 3, Gilgoin Nos. 1 and 2, and Eli Elwah or Hay Meteorites, New South Wales. By A. Liversidge, LL.D., F.R.S., Hon. F.R.S. Edin., Professor of Chemistry, University of Sydney. [*With Plates.*]

XVII.—An important Geological Fault at Kurrajong Heights, New South Wales. By Prof. T. W. Edgeworth David, B.A., F.G.S., F.R.S. [*With Plates.*]

Sections.—The *Economic Science Section* held five meetings at which five papers were read and discussed:—

1. Bank notes *v.* Government notes by R. L. Nash.
2. Imperial Defence, by H. B. Bignold.
3. The Timber Industry and Forests of New South Wales, by A. Duckworth.
4. The overproduction fallacy, by W. Pearse.
5. Some recent co-operative developments, by J. Plummer.

The *Engineering Section* held five meetings during the year at which three papers were read and discussed. The average attendance of members and visitors was 20.

1. Annual Address to the Engineering Section, by H. G. McKinney, M.E., M. Inst. C.E.
2. The Importance of Federal Hydrography, by J. Haydon Cardew, Assoc. M. Inst. C.E.
3. Recent developments in High Speed Railway Construction and Working, by C. O. Burge, M. Inst. C.E.

I would like to draw the attention of members to the arrangements made by the Engineering Section for this year's meetings. In place of holding the customary monthly meeting, at which one, or at most two papers would be read, it has been decided to hold *two* or possibly *three*

Sessions at intervals of a couple of months. Each Session will extend over ***two nights*** at least, and only one general topic will be considered at each Session, a number of papers on different aspects of the same subject being presented for discussion. The first of these Sessions will be devoted to the question of *Water Conservation*, and the second to the problem of *Technical and Industrial Education in Australia*. Already a large number of papers have been promised, and there is every prospect of the new departure producing very valuable results.

Lectures.—A course of five science lectures was delivered during the Session, and were well attended.

June 26th—The rôle of Bacteria in the Production of Disease, by F. Tidswell, M.B., M.Ch., D.P.H., Health Department.

July 24th—The Development of the Dwelling House, by F. W. Woodhouse, Superintendent of Drawing, Department of Public Instruction.

August 28th—Micro-organisms, their Life and Work, by R. Greig-Smith, M.Sc. Macleay Bacteriologist.

October 23—Biology and Every-Day Life, by Professor W. A. Haswell, M.A., D.Sc., F.R.S.

November 27th—The Art of the Bridge-Builder, by Professor W. H. Warren, Wh. Sc.. M. Inst. C.E.

Conversazione.—A very successful Conversazione was held in the Great Hall of the University, on Friday, December 5th, 1902.

Roll of Members.—The number of members on the Roll on the 30th April, 1902 was 375. During the past year 14 new members were elected; the deaths numbered 9, resignations 20, and 16 were struck off the Roll for non-payment of their subscriptions, leaving a total of 344 to date.

The following is a list of members who have died during the year :—

James Comrie ; elected 1856.
J. J. Farr ; elected 1889.
Dr. A. M. Megginson ; elected 1888.
Dr. F. Milford ; elected 1873.
James Milson ; elected 1882.
Sydney Moss ; elected 1882.
Joseph Thompson ; elected 1875.
Dr. G. A. Tucker ; elected 1877.
Rev. Dr. James S. White ; elected 1874.

The Development and Progress of Engineering During the Last Twenty-One Years.

In selecting a subject, or group of subjects, for my address, I have been guided by the practice of my predecessors in the Presidential Chair, who have in almost every case given special prominence to the subject to which they have devoted the greatest attention, and upon which they are most competent to express an opinion. I have therefore chosen the 'Development and Progress of Engineering during the last twenty-one years.' It so happens that the establishment of the Department of Engineering at the University of Sydney dates from 1883, nearly twenty-one years ago. During this period I have travelled on two separate occasions to the principal engineering centres, and have inspected the most important engineering works in the world, so that I am able to speak from personal knowledge on most of the topics dealt with in this address. The past twenty-one years has been a period of great engineering activity and progress in almost every branch of the profession, and I will endeavour to deal with the most important of these as fully as possible, consistent with the limited time at my disposal for a Presidential Address.

Progress in Steam Engineering.—The finest examples of modern steam engines to-day are to be seen in the mail steamers which run from New York to Great Britain and Europe, and also in the large power plants of America and Europe, where they are arranged to drive electrical generators. Some very fine examples of pumping engines exist, such as the Reynold's engine at Chestnut Hill, Boston, U.S.A., which gave a duty of 178,497,000 foot pounds per 1,000 pounds of dry steam, and 173,869,000 foot pounds per 100 ℔s. of coal.

The recent engines designed by Reynolds for the Manhattan Railway Company of New York are also worthy of notice, as each engine consists of a pair of compound engines capable of developing 8,000 horse power when working under its most economical conditions, and a maximum of 12,000 horse power. One excellent feature in the design is the arrangement of the two high pressure cylinders horizontally and the two low pressure cylinders vertically, thus minimising cylinder wear, and saving floor space. Again the cranks are so arranged that eight impulses are given per revolution, which is a great advantage in driving alternating current generators.

One of the most notable examples of marine engines and shipbuilding occurs in the North German Lloyd Atlantic liner Kaiser Wilhelm II., which is one of the largest and fastest ships yet built. The displacement is 27,000 tons, and the engines are 40,000 I.H.P.; the speed is 24 knots per hour. The propelling machinery for the twin screws consists of four four-cylinder, three crank, quadruple expansion engines. The two engines for each shaft are placed behind each other in order to admit of the construction of a transverse watertight bulkhead in addition to the longitudinal partition, so that each of the four engines is within a separate compartment. These engines drive a four-

bladed bronze screw propeller about 23 feet in diameter. The crank shafts and the thrust shaft, 25 inches in diameter, are made of nickel steel; the screw shaft, 25½ inches in in diameter, is of crucible steel, and the whole connecting shafting is of Siemens-Martin steel. Steam is supplied by twelve double and seven single boilers, working at a pressure of 213 pounds per square inch, and having 107,643 square feet of heating surface. The 124 furnaces have 3121 square feet of grate area. The boilers are arranged in four groups, each having a funnel of 16 feet in diameter and 131 feet above the keel. The boiler rooms are ventilated with cowls and eight powerful fans. There are in all 79 engines on board including the main engines, and 124 steam cylinders.

The use of steam jackets, re-heaters, and superheating apparatus for the purpose of the reduction of cylinder condensation have shewn that steam jackets are not very efficient with modern high speed engines, that reheaters produce economy mainly in reducing the loss of power in the low pressure cylinder, and that superheating the steam appears to be the most satisfactory method provided that the final temperature does not exceed 500° F.

The modern method of using auxiliary engines for condensers, the use of feed water heaters, economisers, etc., have resulted in a considerable reduction in the cost of steam power. The characteristic features of modern steam machinery are the use of large units, high steam pressure, compound engines of moderate rotative speed for central station engines; triple and quadruple expansion marine engines, independent condensers and other auxiliaries, with steam exhausted non-condensing through feed water heaters, water tube boilers generally provided with superheating attachments; economisers in the flues, high chimneys, and automatic stokers supplied with coal handling machinery.

Steam Turbines.—By far the most important improvement of recent years in steam engineering is the development of the steam turbine, which is due largely to the labours of the Hon. C. A. Parsons of Newcastle-on-Tyne. The chronology of the steam turbine is interesting as indicating the unequal and erratic progress which may be made in the various branches of the mechanical arts, as well as the anticipation of modern by ancient inventive genius. The reaction turbine dates back to the time of Hero and his contemporary, Archimedes, 120 B.C. The impulse turbine type is credited to Branca in 1629. In 1705 the reciprocating engine appeared, and in 1884 Parsons brought out the first turbine of the multiple-expansion type, combining in principle the fundamental features of both impulse and reaction types. In 1883 was introduced the original form of De Laval turbine, which was of the reaction type and led up to the modern De Laval impulse turbine introduced in 1889. The Parsons turbines in the ill-fated Viper developed a record speed of 37·1 knots per hour in 1899.

The tendency of modern steam turbine development has been along three important lines—first, mechanical simplicity; second, steam economy; and third, speed reduction. The De Laval impulse turbine is at present manufactured in Europe and America in sizes up to 300 horse power. In its present form it is restricted to a somewhat limited field of application in consequence of its unsuitability to fluctuating loads, and its loss of efficiency due to the governing by throttling.

The compactness of the Parsons' turbine, in the words of Mr. J. R. Bibbins, is largely due to the concentration of the working parts into a single moving element, the absence of means for affecting a transformation of motion, necessary in a steam engine of the reciprocating type, and the

employment of the simplest form of motion—rotation—for converting the energy of the working fluid into useful torque. The resultant motion is most suitable for direct power applications in general, and especially so for the direct driving of alternating current generators, a result accomplished with reciprocating engines only through the employment of large fly-wheel capacity, and heroic design of both engine and generators. Parallel working with the turbine becomes the simplest of operations, due to the entire absence of cyclical speed variations, which prove so troublesome and expensive in the case of the reciprocating engine. The speeds at which Parsons' turbines operate further contribute to economy of generator construction by reducing the number of poles required for a given frequency. The weight of the turbine units of 1,500 K.W. capacity is about one quarter that of the reciprocating engine units of the best design per rated horse power. The Parsons' turbine is very economical in steam consumption and compares favourably with reciprocating engines of similar power, more especially at overloads, half, and three-quarter loads.

In the 1,500 K.W. turbines a Kilowatt hour can be produced with 20 lbs. of saturated steam at 150 lbs. pressure per square inch, or with 18 lbs. of steam superheated to 120° F. The larger sizes are still more economical. Parsons' turbines are simple in design, and are adapted for the use of superheated steam without any of the disadvantages such as attend its use in reciprocating engines; moreover the steam can be expanded down to the condenser pressure, and the condensed steam returned as feed water to the boilers entirely free from oil. The advantages of turbines over reciprocating engines may be briefly summarized as follows:—

1. The steam economy at fuel load is at least as good as that of reciprocating engines of similar capacity, but at

overload and underload the economy is relatively greater. Again, the steam turbine maintains its economical use of steam for a much longer period than the reciprocating engine, as it is not affected by cylinder wear.

2. The turbine is capable of utilizing a higher vacuum than the reciprocating engine, by expanding practically down to the condenser pressure.

3. There is no necessity for internal lubrication as in the reciprocating engine, and consequently oil does not find its way into the condensers and boilers when turbines are used, thus obviating serious difficulties.

4. The construction of the turbine admits of the use of superheated steam without disadvantages such as occur in its use in reciprocating engines.

5. There is a considerable saving in oil and much less wear and tear than in reciprocating engines.

6. There is considerable economy in space.

7. The turbine is a perfectly balanced machine, having a uniform torque, and there are consequently no disturbing effects due to unbalanced parts as in the reciprocating engine; so that it does not require heavy foundations.

8. The turbine is especially adapted to high speed vessels, such as torpedo boat destroyers, as there are practically no vibrations such as those which occur in reciprocating engines.

9. Steam turbines of the Parsons' type are capable of driving alternators which will work synchronously with each other, or with properly designed alternators driven by reciprocating engines.

Steam turbines are capable of driving centrifugal pumps of the ordinary or reversed turbine class. A Parsons' steam turbine coupled to three similar centrifugal pumps working in series, and mounted on the same bed plate has

just been tested by Professor Goodman for the New South Wales Government. Saturated steam was used at 57 lbs. pressure per square inch, giving a steam consumption of 27·93 lbs. per water horse power hour. The turbine required 15·6 lbs. of steam per brake H.P., so that the combined efficiency of the pumps was 56%. The pumps were tested against a total head of from 744 to 762 feet, and the water horse power was 235 to 252. The speed of the turbine was 3,300 revolutions per minute. Similar satisfactory tests were made with steam superheated to 95° F.

The steam engine has through nearly two centuries of continued improvement reached the zenith of its career of usefulness, and is in danger of displacement by either one or both of its two thermodynamic superiors, the steam turbine and the gas engine.

Steam Boilers.—Recent progress in steam boiler construction consists mainly in the perfection of details in design to meet the severe conditions of modern practice. Horizontal return multi-tubular boilers are probably still the most widely used type to-day; they give a high efficiency and are of comparatively low cost, although their use is confined to the smaller plants as they are of limited size for high pressures. The use of water tube boilers is rapidly increasing, as they are adapted to large plants, and high pressures, danger from explosion being reduced to a minimum. The Manhattan Railway power house, New York City, contains 64 water tube boilers rated at over 500 horse power each, or a total of 32,000 horse power. Economy of labour and fuel has been considerably increased by the use of mechanical stokers, coal and ash handling machinery.

Considerable attention has been recently given to the use of water tube boilers in the Navy, and the extensive experiments made by the Admiralty on different steam

generators on similar vessels should definitely settle the question as to the most suitable boiler for our war ships; meanwhile the results obtained appear to point towards the adoption of some form of water tube boiler.

The use of petroleum oil as a fuel for raising steam has come again to the front mostly in the mercantile marine, and it has been proposed to build vessels for the Atlantic mail service using oil as fuel, and steam turbine engines of sufficient power to deliver mails from London and Paris to New York in four and a half days. The Red Star liner *Kensington* has crossed the Atlantic with one of her boilers using oil all the time, and oil fuel is now used on the *Alameda* of the A. and A. line. The first voyage of the *Ventura* between Sydney and San Francisco proved also very successful. The advantages consist in a considerable saving of labour in stoking, the running of the burners is exceedingly simple, and present numerous advantages over coal. The fires can be rapidly extinguished and re-lighted. In an official report on the use of oil in the United States Navy, Admiral Belleville states that the efficiency obtained was 40% greater than with coal.

The advantages in oil fuel over coal has been long known, but the cost of oil has prevented its more extensive use; this objection, however, is very likely to be removed by the extension and development of oil trading companies. Messrs. Armstrong and Whitworth have been making extensive experiments on the best methods of applying oil fuel to war ships, and Sir Andrew Noble states that it takes 16 times as long to coal a battleship as to re-fuel it with oil.

Automatic stokers possess features that can undoubtedly make water tube boilers a success, for regularity of fires and uniformity of the same are essential requirements of successful working. Mechanical stokers and liquid fuel will assist the water tube boiler in its future development,

the former for stationary plant, the latter at sea. Oil fuel will certainly be much more largely used in the future than it is at present.

Electrical Engineering.—Electrical engineering has been developed during the last twenty years, mainly to meet the requirements of cities, and is concerned with the generation, transmission, and distribution of electricity for power and lighting purposes. By far the most extensive use of electricity for power purposes occurs in connection with electrical railways and tramways, although a considerable amount of power is absorbed by various industrial establishments. The characteristic feature of this branch of engineering is the Central Power Station where electricity is generated, and which should be conveniently located in regard to the supply of coal and water. There are four ways in which electrical traction has so far presented itself, namely:—

1. The overhead trolly wire.
2. The under-running trolley, grooved conduit.
3. The elevated road with a third rail.
4. The tunnel with its side, ceiling or bed contact.

The magnetic contact system has not passed so far beyond the experimental stage, and the use of storage batteries carried on the cars, although used in many cities in Europe, has not given entire satisfaction. The storage batteries enable the cars to run through the crowded portions of the city without the use of the overhead trolley, which latter is used in the less crowded portions. By far the most widely used system is the overhead trolley on account of its cheapness, rapidity of construction, and adaptation to the conditions of suburbs. The slotted conduit is suitable for cities and crowded thoroughfares, as there are no poles or overhead wires, and all the charged conductors are underground. The elevated electrical rail-

road with the third rail has been successful at Liverpool, Chicago, New York, and Berlin. Berlin is the most modern and has a much better appearance architecturally than the others. The modern electrical underground railway has made rapid strides since those installed at Buda Pesth, London, Paris, and Berlin.

In connection with the introduction of electric traction to the Sydney tramways, it may be stated that the first electric tramway in New South Wales was opened for traffic on 9th November, 1890, when the section of line between Randwick and Waverley was operated on the overhead system from a small power-house situated at Randwick. The practicability of the system having thus been established, the whole of the material was removed in September 1893 to North Sydney, and a length of over two miles on the Military Road was equipped as an extension to the existing cable line. Current was furnished from two 100 kilowatt generators belted on to the shaft of the engine which operated the Milson's Point cable line. This short line was subsequently extended and finally the cable line was 'electrified,' so that the North Sydney service is now entirely electric. The next extension of the electric system took place in October 1898, when the extension from the Ocean-street cable line to Rose Bay—1 mile 24 chains—was electrically equipped, the power being supplied from the Rushcutter Bay cable power-house.

In 1896 a bill was passed empowering the Railway Commissioners to convert the whole of their steam service—then about forty miles of double track—to electric traction, and in December 1899 the first of the city electric services, viz. the George-street and Harris-street line was put into operation. The current was furnished from the new power-house at Ultimo, the plant consisting of four 1,250 horse power horizontal engines, each coupled to an 850 kilowatt

direct current, 600 volt compound railway generator. Subsequently the Western suburban lines were converted to electric traction in the following order, viz., Dulwich Hill, Cook's River, Glebe and Leichhardt.

With the conversion of the Balmain line on August 9th, 1902, the new high tension three-phase plant was put into regular operation. This plant consists of three 1,500 kilowatt, 6,600 volt, 25 cycle General Electric Company's three-phase alternators, direct driven by vertical compound Allis engines with 32 inch and 64 inch cylinders, and 60 inch stroke at 75 revolutions per minute, and thirty-two Babcock and Wilcox water tube boilers with automatic chain grate stokers. Current is distributed from the power house by means of duplicate underground paper-insulated and lead-covered cables to each of the five substations located respectively in the City, Newtown, Waverley, Randwick, and North Sydney. Each substation is equipped with two 450 kilowatt rotary converters, six 175 kilowatt static transformers and two 500 ampere hour storage batteries, with the necessary switching gear and boosters. From the substations the over head line is supplied at 600 volts. The total length of single track of tramways at present operated is about 160 miles, of which about five miles are still operated by cable and twenty-five by steam, the remainder being on the overhead electric system. It is proposed to eventually work the whole system electrically, and the work of conversion is still in progress. It may be added that about 400 cars are now in daily service, requiring a maximum output of 6,000 k.w. from the power house.

In addition to supplying power for the large tramway services, power is also supplied from Ultimo for lighting 300 arc and 6,000 incandescent lamps in the railway yards and stations, also for supplying power for forty-five small

motors for the Darling Island grain elevators, besides a number of motors for operating machines, cranes, traversers etc. at the Eveleigh railway workshops as previously mentioned. Amongst other uses of current from Ultimo are the operation of the Pyrmont and Glebe Island swing bridges, and the twenty-two low level sewage pumping stations which are being put into service, and the illumination of the Sydney Cricket Ground by means of 20 arcs and 1,500 incandescent lamps for evening performances.

The use of electricity in connection with the railways has also been largely increased, an important improvement instituted by the Commissioners to increase the safe working of trains over so much single line road as exists in this State being the substitution of the electric tablet and electric train staff systems for the old hand staff and ticket permits, which they found in use when they commenced control. The possibilities of working have also been immensely enhanced by the adoption of all kinds of telephones, phonophores, etc.

In regard to the application of the polyphase system to electric railways and tramways a very great saving would be affected if suitable car motors could be constructed for utilizing the polyphase current without the elaborate system of rotary converter substations now found necessary. A satisfactory alternating current motor for tramways has so far not appeared, but such motors have been used on electric railways in a few instances, the most recent of which is on the experimental Military Railway near Berlin, where Messrs. Siemens and Halske have successfully applied 10,000 volts directly to the car motors.

In the system of electric traction proposed by Mr. B. I. Arnold, each motor car is equipped with a single phase alternating current motor, of which both the armature and field are capable of revolving upon a common shaft either

separately or together. Attached to armature and field are two engines, one to each, which are so constructed that they may be used either for compressing air which is stored in a reservoir carried on the car, or for driving by means of compressed air the portion of the motor to which they are attached.

The motor which is designed to fulfil the average propulsion requirements of the car, is intended to be maintained at constant speed (synchronous with the driving generator), and at constant load. It is claimed that the motors work always at maximum efficiency, and that the variations of load will be diminished. No energy is lost in brakes, as it will be stored up on descending grades for future use. There is a saving in copper conductors in consequence of the high tension of the line, namely 15,000 volts. There are static transformers on each car for reducing the tension to 200 volts.

Water Power.—Australia does not offer many opportunities for the development of water power, although a few isolated examples may be mentioned. It is mainly in America and Europe that the great developments have recently taken place in the utilization of water-power for generating electricity for transmission to the city or town, and where it can be used in a great variety of ways for power and lighting purposes. The utilization of water-power for generating electricity has given an impetus to the design and construction of turbines within recent years, although there is no doubt that hydraulic machinery in the form of current wheels existed in China and on the Nile 3,000 years ago. The modern water turbine is entirely a theoretical invention, and, unlike the steam engine, it is the direct outcome of mathematical investigation. Its development also in Europe, where its progress has been most marked, has also been purely on theoretical lines. The

best examples of turbine work are to be found in Switzerland, where also some of the best turbines installed in Europe have been manufactured. The application of the laws of hydraulics to the action of water in simple radial or parallel flow turbines being for a long time well understood, the highest hydraulic efficiency attainable for the different types could be easily calculated; the actual efficiency is obtained by multiplying the hydraulic by the mechanical efficiency, giving from 75 to 85 per cent., which is practically realized to-day with turbines of the most approved design.

The early turbines were of the radial flow type, but this was soon replaced by the parallel flow turbine which on account of its simplicity and cheapness became the standard type, but the introduction of electrical transmission requiring higher speeds and better speed control necessitated a different type of turbine. Modern requirements appear to indicate the following types as the most suitable according to John Wolf Thurso :—

1. For low heads, up to say 20 feet: Radial inward flow turbines of the Francis type with vertical shafts, the foundation masonry usually forming the turbine case, draft tubes being frequently employed.
2. For medium heads, say from 20 to 300 feet, radial inward flow reaction or Francis turbines with horizontal shafts and concentric or spiral cast iron cases with draft tubes.
3. For high heads, say from 300 feet: Radial outward flow, full or segmental feed, free deviation turbines with horizontal shafts and cast iron or wrought iron cases, frequently with draft tubes, or a modified form of the Pelton wheel.

A large number of turbines are in operation in America and Europe, among which may be mentioned the 5,500 HP.

turbines at the great Niagara Power House, where each alternator is driven by an upper and lower turbine; the latter has no end thrust, but the upper has an upward thrust and carries the shaft rotating field and runners, weighing in all 80 tons. These turbines have a very perfect device for regulating the speed, designed by Picard, Pictet and Co., Geneva, Switzerland.

In Europe the high price of coal has very considerably encouraged the development of water power, and in some cases supplementary steam plants have been installed to make good the deficiency in water at certain periods in the year, thus necessitating a duplicate set of machinery, but even this expense is considered justifiable under the circumstances. At Turin and Milan, Isarwerke, Munich, Lauffen, Heilbronn, Baden, Soluthurn, and at many other places, the central station in the city is supplied with synchronous motors driven from the electrical generators at the distant hydraulic station; as well as a complete set of steam engines and generators which work in conjunction with the synchronous motors. At Switzerland also, there are several hydraulic installations which have supplementary steam power, such as the municipal stations at Zurich and Lucerne. It should be noted that in all the cases mentioned, the synchronous motor driven generators are operated in parallel with those driven by reciprocating engines.

Among the more recent water power plants which have been developed in Europe, may be mentioned the municipal light and water works at Schaffhausen, where three Jouval turbines have been replaced by three Francis turbines of about 430 HP. each, with more perfect speed regulation. These gave 86·6% efficiency at full load, and 77% at half load. At Chèvres power plant there are five old conical turbines of 800 to 1,000 HP. at 80 revolutions per minute, and ten

recently installed double centrifugal turbines of 900 to 1200 horse power at 120 revolutions per minute. The head varies from 14 to 26½ feet, and the volume from 4,230 to 42,300 in an irregular manner, often without warning. The new turbines have each two wheels, of which the lower one is designed to work under the higher heads, and there are two sets of guides for each wheel, one above the other. The water flows in a direction parallel with the axis into each wheel, both from above and below, and leaves at the circumference in a radial direction. The wheel casing on both the upper and lower turbines is so arranged as to admit more pressure to the under side than the upper, in this way so far balancing the pressure that an overhead suspension bearing may be used. At Lyons there are 22,000 HP. installed, for which Francis turbines are used. The water is taken from the river Rhone above Lyons by a canal 11½ miles long, the power house being about 1½ miles from the lower end; the canal varies in width from 197 to 344 feet and is 8¼ feet deep in the shallowest part. The installation consists of eight 1,250 HP. turbines coupled to alternating current generators directly above them, with three 250 HP. turbines for exciting the fields of the alternators. The eight 1,500 HP. turbines have been added more recently, and are of the double type; they are designed to work efficiently with a greater fluctuation of head than the others, and are hydraulically balanced. The regulation is by Fink swinging gates, worked by a servomotor under oil pressure.

In America a power plant of 57,000 HP. was completed last year at Sault Ste. Marie, Michigan, for the Lake Superior Power Company, at a cost of £800,000. Each hydraulic unit is composed of four double turbines arranged horizontally, of 568 HP., and from 81 to 82% efficiency. The electric units consist of 400 KW. alternating and direct current Westinghouse generators.

The reversed turbine, or turbine pump, is a great improvement on the ordinary centrifugal pump, and like the turbine it has been developed on purely theoretical principles. Turbine pumps tested in Switzerland against a head of 428 feet gave an efficiency of 76%, whereas the ordinary centrifugal pump which is suitable for low heads only gives from 50% to 65% efficiency.

The most noticeable feature in the hydraulic power plants which have been recently developed is the utilization of very large powers in a single power station, such as 20,000 to 100,000 HP., having in some cases large units such as at Niagara, 5,500 HP., by means of which enormous energy concentrated in the first instance, may be conveniently distributed over considerable distances by means of electrical transmission, and supply the requirements of varied industries and other useful work.

Electrical Distribution of Power in Industrial Establishments.—The use of electrical motors driving shafting and machinery, which is now so extensively used all over the world, is one of the features of the last 15 years. The economy obtainable by the use of electric motors as compared with shafting and belting is now firmly established. In a machine shop driven by a single engine through belts and shafting, the latter use up from 60 to 80% of the total power developed by the engine, whereas with electrical transmission from the engine to the machinery, the actual power delivered is from 65 to 70%, or a loss of 30 to 35% when the main generator is lightly loaded, and 20 to 25% when fully loaded. The chief merit of the electric motor in factories, mills, etc., lies in the superior ease of operation and speed regulation, by means of which a much greater output from the machine is attainable, and the cost of production is reduced as much as 30% in some cases. The speed in continuous current

motors is generally controlled by three methods:—

1. Varying the field strength of the motor.
2. Providing two windings and two commutators on a single armature which may be connected in series or multiple for high and low speeds respectively.
3. Providing a plurality of supply circuits, each of a different voltage, and interlinked so that the voltages may be added, the motor armature being connected across whichever of the supply circuits will produce the proper speed.

It is usual to combine the first method with one of the others. Where it is necessary to drive machinery at a constant speed, the synchronous motor using alternating polyphase currents is the best. Asynchronous or induction motors are exceptional in their simplicity of construction, ease of operation, and general reliability, under unfavourable conditions of care and surroundings. For elevators, hoists and similar service the induction motor is provided with a variable resistance in the secondary circuit, which allows its speed to be varied within wide limits. These motors have a powerful starting torque. For driving ordinary machine tools requiring constant speed, or for crane service when suitably modified in design, the squirrel-cage secondary is the most suitable. The wiring will be the simplest for direct current distribution at one voltage. The three-wire direct current, and the three phase, and three-wire two phase alternating current systems are next in order of simplicity, but the four-wire two phase alternating and the multivoltage systems are more complex and costly.

Bridge Building.—The history of the bridge builder dates from the period of classic antiquity, but its development during the nineteenth century is due to the following:—

1. The invention of the various processes for the manufacture of cast iron, wrought iron, and structural steel.
2. The experiments made in order to determine the physical properties of the material of construction in the first instance by such men as Telford, Rennie, Rondelet, Tredgold, Dufour, Sequin, Hodkinson, Stephenson and Fairbairn, and more recently by the elaborate investigations and researches conducted in engineering laboratories provided with special forms of testing machines and apparatus for accurately measuring stresses and the deformations produced by them.
3. To the mathematical investigations, aided by experimental researches on elasticity and the calculation of stresses and deformations in structures by such men as De Saint Venant, Claperon, Mohr, Winkler, Bach, and Castigliano.

It is interesting to note that Robert Stephenson actually built the Menai Bridge in 1846-7, which consists of a continuous box girder of three spans, each 466 feet, large enough for a train to pass through it, while Claperon's method of calculating the stresses in such girders was not published until eight years later.

The art of the bridge-builder, both in its theoretical and practical aspects has gradually become most precise and exact in every particular, and to-day there is no branch of engineering where science and experience has been so completely united, or where greater success has been achieved in economy of material, manufacture, and efficiency. The first real iron bridge was built by Abraham Darby in 1776, of cast iron, and cast iron was used in the compression members of trusses in America as late as 1875; the use of structural steel, such as we understand it to-

day, was unknown 25 years ago. The displacement of wrought iron by steel is the most important feature in bridge building during the last twenty-five years, which, coupled with the gradual improvement in the quality of the material due to the more perfect methods adopted by the steel manufacturers, as well as the equipment of the workshops with special tools and appliances for manufacturing the various members of bridges, has rendered possible the attainment of such structures as the great Forth Bridge with its two spans of 1,710 feet, as well as many large bridges constructed in America, such as the 550 feet spans across the Ohio at Cincinatti and Louisville, the Red Rock and Memphis cantilevers, also more recently the great cantilever constructions at Pittsburg, and the 1,800 feet span now being constructed across the St. Lawrence River, near Quebec. The wonderful progress in the art of bridge building made during the last few years may be realized by considering the various designs prepared by American engineers for crossing the Hudson River at New York, which include a suspension bridge of 3,100 feet span carrying six lines of railway.

Various designs have been submitted by British, American and German engineers for the Sydney Harbour Bridge, which if constructed, would be ranked among the most important bridges of the world.

The modern treatment in the design of the stiffened suspension bridges which is illustrated by the East River Bridge at New York City, 1,600 feet span, and by one of the proposed designs for the Sydney Harbour Bridge.

The tensile strength of the steel wire used in the East River Bridge was found to be 223,000 lbs. per square inch. The cables are thoroughly saturated with waterproof composition wrapped with a triple layer of canvas and an outer covering of steel plate, and the whole will be carefully

painted from year to year. Messrs. Burr, Cooper, and Morrison reported that the cost of the Hudson River Bridge would be £7,073,400, if the suspension type were adopted, and £10,225,600 for a cantilever of the same capacity.

The steel wire used in the modern suspension bridge has a tensile strength of 220,000 lbs. per square inch, and with such wire it would be possible to build a bridge suitable for the heaviest railway traffic of 4,000 feet span with perfect safety, but since the length of the span attainable depends upon the weight and strength of the material used in the construction, it follows that if larger spans are built in the future, the strength of the material must be considerably increased.

It is difficult to predict what improvements may be made in the future, and no doubt many surprises await us during the next 25 years; but the scientific and practical work of the metallurgist and the engineer may render practicable the use of some alloy, such as nickel and iron, having greater strength and elasticity than modern structural steel. The physical properties of the alloys of nickel and iron are well understood, but the material is very costly, and there is some difficulty in rolling plates of nickel steel containing the percentage of nickel most suitable for bridgework.

The Design and Construction of Foundations.—Generally the methods adopted have been more or less used for a considerable time; but the chief developments in this branch consist in the application of the freezing process in sinking shafts and foundations, mainly in the United States, and in the method of open dredging in such cases where the ordinary pneumatic process would be unsuitable, in consequence of the effect on the workmen at great depths, necessitating correspondingly great pressures of air.

The piers of the Hawkesbury River Bridge, founded 170 feet below high water and 126 feet below the bed of the river, are at present the most remarkable example of the open dredging process; but equally difficult conditions may be encountered in the Sydney Harbour Bridge in one of the piers. The pneumatic process is by no means new, but it has been considerably improved in detail during the last few years, mainly in the design of the air-locks and caissons; but the effect on the workman under great pressures producing what is known as Caisson disease, is not entirely under control, although much has been accomplished in this direction by careful regulation of the changes in pressure, more especially in leaving, by the use of elevators, and by general attention to the health of the workmen employed. Probably 150 feet is about the limit attainable by this process, although so far there are no examples of so great a depth having been attained. In the new East River Bridge the depth reached was 115 feet from high water, but the air pressure was not equal to this head of water, in consequence of the retentive character of the material passed through.

The pneumatic process has been used in a few cases in Australia, but in other parts of the world it has been employed to a considerable extent, both in the foundation of bridge piers, quay walls, and in connection with shield tunnelling under rivers. In America it has also been used recently in the foundations of the high buildings for which that country is famous, and many interesting examples have been described in American technical journals, such as the *Engineering Record* and *Engineering News*.

A considerable amount of work has been accomplished in depositing concrete in sub-aqueous foundations, forming a monolithic mass capable of carrying the heaviest loads.

Testing the Materials of Construction.—The art of engineering construction in all its various branches is daily becoming more and more exact in consequence of the accumulation of data on the physical properties of materials mainly derived from the experiments which are continuously in progress at the various engineering laboratories associated with universities and technical colleges throughout the world.

In order that the great mass of this valuable information should be more completely understood and the results comparable, it has long been recognised that standard methods should be adopted as far as possible:—

1. In the form and dimensions of test specimens of various materials.
2. In the machinery and appliances used in producing the stresses and measuring their effects.
3. In maintaining the conditions under which the tests are made as uniform as possible for the particular experiment in question.
4. In properly recording the results obtained, so that their true value may be correctly appreciated.

No doubt a great advantage would be gained in this, as in every other department of scientific research, if the metric system were universally adopted. The most important and in every respect the most representative society in the world in this branch is the International Association for Testing Materials, founded mainly by Professor Bauschinger of Munich, who was President until his death. Professor Tetmajer of Vienna succeeded Professor Bauschinger, and is still President. The list of members include the most eminent scientific men and engineers in Europe, America, and Great Britain, and meetings are held each year in one of the principal cities for reading and discussion of papers, and receiving the reports of com-

mittees appointed to consider special problems. The object of the society is to encourage research on the physical properties of the materials of construction, and for the establishment of uniform international methods of testing. A perusal of the published papers reveal the vast extent and usefulness of the work accomplished, both from a purely scientific and technical view. I suggest that all those interested in physical science, engineers and architects, should become members of this association, and as I happen to be the oldest member amongst British subjects I shall be glad to receive the names of anyone desiring to become a member of this important society.

The most comprehensive and valuable collection of papers and data on this subject published up to date is to be found in the communications presented before the International Congress on the methods of testing the materials of construction held in Paris in July 1900. The following papers describe some of the experimental investigations made at the P. N. Russell Engineering Laboratory, University of Sydney:—

The adhesion of cement mortars to bricks (1884).

The strength and elasticity of Australian timbers (1892)

The unification of the methods of testing materials and the precautions necessary in the accurate determinations of the various coefficients of strength and elasticity (1897).

The effect of temperature on the tensile and compressive properties of copper (1897).

Some physical properties of nickel steel (1898).

Investigation on the strength, elasticity and other properties of trachyte (1899).

Experimental investigation of the strength of brickwork when subjected to compressive and transverse stresses (1900).

The strength of concrete (1901).

Investigation in regard to the comparative strength and elasticity of Portland Cement Mortar and concrete when reinforced with steel rods and when not reinforced.

An investigation has just been completed by Mr. A. Boyd, B.Sc. and B.E., on the elastic deformations in fly wheel rims at different speeds of rotation. Experiments are still in progress on the elastic deformations and ultimate strength of various materials. Special rotating machines and apparatus for measuring the deflection during rotation have been designed and made in the laboratory for these researches.

In addition to the foregoing a considerable number of experiments have been made on joints and connections, structural steel, girders, and structures.

Irrigation.—The beneficial effects of the application of water to arid soil in order to increase its fertility and render it more capable of producing food for the people, has been abundantly demonstrated in various parts of the world. Generally where the conditions are favourable, and where the necessary works have been well considered, the results show a satisfactory return, and form a profitable field for the investment of capital and for the operations of the merchant and financier.

In Egypt the results of the periodic flooding by means of the Nile are extraordinary, and the narrow fringe of land along the banks of the river supports a population of nearly five persons per acre. The most important works are the barrages, or dams, below Cairo which regulate the flow of the Nile at the point where it divides into the Rosetta and Damietta branches and the delta of Lower Egypt begins, also the great regulating dam at Assouan which was opened last year. Much work has also been

done in improving the condition of the irrigation canals, particularly by works for reducing the excessive deposit of silt.

In the United States of America irrigation has been successfully applied on a considerable scale, and in California the results have been most striking. In the countries bordering on the Mediterranean irrigation has been practised from times as remote as in the lands of the East. In Northern Italy, Piedmont and Lombardy irrigation has been successfully applied over about one-third of the whole productive area, and many interesting works have been constructed, including the Cavour Canal.

Irrigation in India is interesting to us, because it was there that English engineers first came in contact with a system which had been in existence for ages, and had enabled a dense population to maintain a struggle for existence against adverse conditions.

From a careful consideration of the conditions existing in countries where irrigation has been successfully applied, it should be possible to devise schemes and construct irrigation works in Australia, which would go a long way towards reducing the disastrous effects resulting from droughts. Irrigation has been already applied in most of the Australian States with more or less success, but only on a moderate scale. It is desirable to deal with the subject in a more comprehensive manner, and this appears likely to be accomplished in New South Wales.

Proposed expenditure on water conservation works.— I am indebted to Mr. L. A. B. Wade, Engineer for Water Conservation, for the following description of works proposed in this branch. In view of the proposed expenditure under the provisions of the Water and Drainage Bill of £1,000,000, extending over a period of five years on works

of water conservation, irrigation, and drainage, it is of the utmost importance that it should be now definitely decided upon what general lines that expenditure is to proceed; bearing in mind that the sum to be provided is probably less than a tithe of what is required to carry out a comprehensive system of works sufficient to materially affect the conditions of settlement over the State, and that, therefore, the most necessitous areas can only be dealt with.

One of the lessons to be learnt from the present drought is that the policy of the past to induce a class of small settlement in the semi-arid and arid areas of the State, particularly in the latter, has largely failed, while at the same time it has been shewn that there are immense quantities of land in the humid and semi-humid areas capable of carrying a closely settled population, the facilities for such settlement only being wanted. The future policy of the State will be, no doubt, to afford these facilities, whether by construction of railways or purchase of large freehold estates, and ensure closer settlement in the future on a sounder basis.

The climate conditions referred to may be defined as including the following areas:—

Humid—The eastern slopes of the Dividing Range.

Semi-humid—Tablelands and western slopes as far as foothills of Dividing Range.

Semi-arid—West from the foot-hills 100 to 150 miles.

Arid—The remainder of the State.

A very large number of small and isolated works will be required over these areas which can be separately dealt with on their merits. It is proposed now to define a general scheme of larger works to be constructed.

Some of the richest lands in the State are the coastal swamps in the humid area, which in their virgin state are useless for any purpose, but when drained are capable of

carrying a closely-settled population. Most of these swamps are situated close to the coastal rivers, are easy of access, only requiring the necessary drainage works, and perhaps in addition works of water supply, it being found with swamps of large area that, when drained, artificial means of supplying water for stock purposes have usually to be resorted to. Outside of the swamp lands in the humid and semi-humid areas facilities for water conservation exist on the undulating country within the means of the majority of settlers, and a small expenditure only in this direction should be necessary. With a view of offering facilities for closer settlement, a proportion of the funds to be provided under the Bill should be expended on swamp drainage and water supply.

Drainage works are now in progress on the Coopernook Swamp on the Manning River, while works have just been completed on the Duranba Swamp on the Tweed River. Numerous schemes are under preparation for dealing with other of the coastal swamps, but I would recommend that works be put in hand in connection with the Macleay Swamps, which represent an area of 60,000 acres of most valuable land, capable of close settlement.

The most pressing want at the present time is without doubt to make it possible for those who have been drawn to the arid areas and expended capital and labour to remain there with a fair certainty of making a living. Outside of the claims of the individual, it is clearly to the detriment of the State as a whole that any of its lands should be allowed to go out of occupation as have large areas recently in the Western Division. These areas become breeding-grounds for noxious animals and plants, and cause damage probably far in excess of the cost of providing facilities for their settlement, so that it is therefore to the interests of the State to promote larger

settlement by the provision of water on stock routes, and where necessary on the land itself, and it is a duty owing to all classes of settlers, as well as to the State, that the land should be made fit for profitable occupation.

It is beyond question that the greater portion of the funds to be provided under the Bill should be expended in the semi-arid and arid areas, and the most reasonable apportionment over those areas is to allow the claims for first expenditure to those with the lesser rainfall. It appears also reasonable that where different sources of water supply, whether surface or subterranean, traverse both semi-arid and arid areas, and which sources are not sufficient for the supply of both, that the more arid area should have the greater claim, and the policy of the State should be to apply the available water proportionately to the want of rainfall.

The total supplies of water available from all sources are not sufficient to deal with the whole of the arid area of the State in dry seasons; it therefore follows that the fullest use should be made of every source, whether surface or subterranean, and in districts where the two overlap, each should be considered in conjunction with the other, and their limitations kept in view, so that no waste either of water or expenditure occur.

As regards the class of work to give the best results for the expenditure, each unit area must be considered separately in connection with the surrounding conditions, and where such works are to be placed under trust, and interest and sinking funds provided, they must be consulted as to the class of work to be provided.

Dealing first with surface waters—the simplest and cheapest method of conservation is by the damming of natural channels. A glance at the map will show that

comparatively small areas only can be dealt with in this manner; also it should be borne in mind that landowners adjacent to a natural channel with a flow of water once or twice only in a year are in a much better position than those holding land back from channels, and are in less need of assistance, from the fact that they have a reliable source of supply which requires simple and cheap works only to store water, while the holders at the back have no reliable sources of supply and storage works are much more expensive. When storage works in a natural channel are not for the benefit of the general public but for private individuals, the conflict of interests in a storage for the supply of several holdings would be the only justification for the construction of the works. Where only one holder is affected, the Water Rights Act provides ample powers for private enterprise in that direction.

Some of our main rivers can be dealt with only by the construction of small storage works along their channels and ana-branches, and a great amount of good can be done in this way for settlers adjacent to them; but some of the most necessitous areas can be supplied only by diversions on a large scale from the rivers that are capable of being dealt with in that manner. People so situated back from river channels are deserving of consideration before those on the river banks, and large works for their benefit should be initiated. This claim has already been recognised by the Government in certain areas by the construction of artesian bores and channels, the aggregate expenditure on which will probably equal that of a large canal scheme.

The records and observations made by this Department during the past 19 years, of the heights and discharges of the various rivers of the State, enables a close estimate to be formed of the areas of country that can be supplied

from these sources. Each surface source of supply will be now taken in detail.

Murray and Murrumbidgee Rivers.—The Murray and Murrumbidgee are the only rivers in this State that give a steady volume of water and can be relied on. Reference to the map shows that over the area that can be supplied from these rivers in the Murray-Murrumbidgee basin, the mean rainfall ranges from 20 inches at the upper to 11 inches at the lower end. All of the schemes previously propounded for the use of these waters provided for taking off channels from the river at the point nearest to the source that difficulties would allow, the proposed point of offtake on the Murray being slightly below Albury, and on the Murrumbidgee slightly below Narandera. It is possible to supply the country with water from these points to Gol Gol on the Murray, which is only a short distance above the confluence of the Darling. The departmental records of the discharges of these rivers show that the amount of water available is totally inadequate for the supply of the whole of this area. The application of the principles already put forward of applying the available supply to the most arid areas, and that where two sources overlap each should be considered in conjunction with the other, necessitates a very careful investigation of this area, and perhaps the re-casting of the schemes already propounded. As regards water supply for stock purposes only, it is probable that over the whole area between the Murray and the Murrumbidgee, west of Corowa and Narandera, there exists a good underground supply that can always be drawn upon from bores or wells, by pumping in dry seasons, to supplement the supplies stored in tanks sufficient for all stock purposes. If such be proved by putting down a series of trial bores, then any channel for the supply of water for stock purposes only should be constructed to command the

country west of a line joining Deniliquin and Hay. As in any case there will certainly be a surplus available for irrigation, it will be a matter for very careful consideration where that water is to be used, due weight given to relative average rainfalls, areas of Crown lands, areas of good irrigable lands, and the interest that can be provided on the cost of the schemes under the different conditions. It is contended by the landholders east of the latter line mentioned, that the productiveness of the lands within that area should be further increased by the application of this water to the soil and a still closer settlement induced. I lean to the opinion myself that this water should be reserved for the area mentioned west of that line, to make that country fit for profitable occupation, it being the most arid portion of the Murray Basin in New South Wales. This scheme would comprise a canal taking off from the Murray at Tocumwal, crossing the Billabong at Conargo and connecting to the Murrumbidgee at Pevensey below Hay. The channel would be continued from the Murrumbidgee across the Lachlan at Oxley and past Arumpo to Gol Gol. No definite conclusion can be arrived at regarding these schemes until an arrangement is arrived at regarding the allotment of the Murray waters to the different States, but meanwhile the whole area should be examined, and all areas of irrigable land classified and charted. Surveys made of the proposed canals from the Murray at Tocumwal and the Murrumbidgee at Pevensey and the existence of underground water tested by a series of trial bores. Detail estimates can then be prepared of each canal scheme propounded and a conclusion arrived at as to what scheme will result in the greatest good to the State. After the allotment of the Murray waters is arranged, it would be as well to put in hand the construction of the first section of the channels from the offtakes decided upon, and clinch the claims of this State, which has always been rebuked in the

past for not having taken advantage of any rights from the Murray that it might have had.

The first sections of the channels constructed could be utilised for the supply of water down natural channels until funds were available for the construction of the whole scheme. There is scope in the Murray-Murrumbidgee basin for the construction of a few small dams on the Billabong and its ana-branch creeks, but the most necessitous areas are those away from those creeks that can be served only by the construction of artificial channels as proposed. The works that have been constructed up to the present in this area consist of the diversion from the Murray into the Tuppal and Eagle Creeks, from the Edwards into the Wakool River, and from the Murrumbidgee into the Yanko Creek; there is small scope for further work of this nature, they comprising most of the practical diversions.

The area that can be supplied from the Lachlan forms a portion of the Murray-Murrumbidgee basin, the Lachlan itself being an affluent into the Murrumbidgee. The departmental records shew that in dry seasons the flow ceases, and that a supply for stock purposes can be maintained only with the assistance of storages. This river affords exceptional natural facilities for the diversions and distribution of water by means of the Willandra Billabong into the back country over an extremely arid portion of the State; but unfortunately, except in good seasons, the supply is not on a par with these facilities. In the first instance the greatest good can be done by the construction of a succession of small storages in the channel of this stream. The whole river should be dealt with in this way, beginning from the lower or most arid end and working upwards in the first instance to the Willandra Billabong. This, besides storing, will result in an ultimate

saving of water when the flow re-commences after a dry spell, experience shewing that less water is required for filling up dams than is lost by absorption in most dry channels. Even with the assistance of these storages, it will be only in good seasons that irrigation can be carried on to any extent along the river banks by means of pumping. A storage has been provided at Lake Cudgellico, which will in average seasons act as a balance reservoir and equalise the flow in the Lachlan, Willandra, and Middle Billabong channels below that point; but if a further equalisation is demanded between good and bad seasons, it will be necessary to construct a large storage on the upper river above Cowra, surveys of which have been completed, and all details are available. This will be a matter for the future, if demand arises and interest is forthcoming, on the expenditure.

The works now recommended are a continuous series of weirs in the river channel and the improvement of the cuttings at the head of the Middle Billabong and Willandra Creeks. It has been contended by the landholders and residents on the Lower Lachlan that the diversions down the Willandra and Middle Billabong Creeks are detrimental to their interests, but the construction of the storages proposed should remove these objections and at the same time provide a larger supply down those creeks. These objections have in the past been raised on account of a certain amount of natural irrigation of pasturage by flooding on the lower river being lost owing to these diversions; but in regard to this, two things should be borne in mind—first, that such flooding has on most occasions been caused by the diversion of water from the main channel by artificial means, and that when the flooding takes place naturally there is ample water for all purposes; and second, the greatest good must accrue to

the State by the widest distribution of the available water for stock purposes.

The works constructed on the Lachlan consist of diversions down the Middle Billabong and Marowie Creeks, the Willandra Billabong, the Booberoi Creek, with weirs in the river at each of these places and storage works at Lake Cudgellico; it is proposed to improve the works at the Willandra Creek by raising the weir and widening the cuttings at each place. It is also proposed to improve the inflow into the Lake Cudgellico storage and the construction of a weir in the river, and to construct a series of weirs in the Lachlan Channel from between the Willandra Weir and Oxley.

Darling River.—The lower portion of the Darling River between Bourke and Wentworth traverses an area similar in aridity to that already dealt with to the west of Hay in the Murray-Murrumbidgee Basin. Facilities exist over the lower portion of this area for the diversion of supplies down the great ana-branch and Tallyawalka Creeks.

Large areas of lakes are connected with each of these systems, a few of the most remarkable of which it will be advisable to fill for storage purposes and the remainder utilised for irrigation. The works required to secure a constant supply will be of an expensive nature, and probably would not be justified for the supply of stock only, but, combined with a moderate amount of irrigation, I feel confident that it will be found that the works will return interest on the expenditure. Surveys in connection with these proposals have been retarded on account of the bad seasons, but it is hoped the proposal in connection with the great anabranch will be completed very shortly. In pursuance of the policy laid down, the first should be put in hand on the lower and more arid end of the river, and in dry years that area should have the first claim to the available flow in the river.

Above Wilcannia a few small diversions into anabranch creeks, by means of cutting, are the only works for which facilities exist on the Upper Darling. Beyond that, pumping for a small amount of irrigation along the banks of the channels must be left to private enterprise. No works have been carried out in this area with the exception of the experimental lock and weir at Bourke.

With the exception of the Bogan, all of the tributaries of the Darling traverse the artesian area to a greater or less extent, and where these two systems overlap, both sources of supply should be kept in view, so that there is no waste of water or expenditure in any schemes projected.

The Bogan River has a small catchment area compared to its length of channel. The flow in average seasons seldom runs throughout its length, and in dry seasons through only a short length of the upper river. The only method of dealing with the stream is by the construction of a continuous series of storages by low weirs over its whole length. Even then it is probable that in dry seasons there will be a shortage at the lower end. The supply in the length below Nyngan can, however, be supplemented by diverting water from the Macquarie River down the Gunningbar Creek. Objections to this course have been raised by the residents of the Lower Macquarie, particularly on and below the Macquarie marshes, on the grounds that they have a greater right to the water for irrigation purposes by natural flooding. The contention of the department against this is that the greatest good must accrue to the State as a whole by the widest distribution of the waters for stock watering purposes, the surplus being available for irrigation. The landholders on the Macquarie below the Gunningbar diversion are also within an area where fairly large

supplies of artesian water are struck at a moderate depth, while the Bogan River is outside of that area.

If the utmost use is to be made of the Macquarie waters in average and dry seasons, it will be necessary to construct a continuous series of weirs in the Macquarie channel between the Warren Weir and the Barwon to retain water for stock purposes; it may be necessary to provide for filling those below the Macquarie Marshes from artesian bores. Those above would always be filled by the river flow, sufficient water would then be diverted for the supply of the Gunningbar, Duck and Warren Creeks; and the Bogan River, which are situated outside of the artesian area, and have no record sources of supply.

The works constructed in the Macquarie consist of diversions down the Ewenmar, Belaringar, Gunningbar, Duck and Crooked Creeks with the weirs for this purpose in the river at Gin Gin and above Warren. It is not proposed to construct any further diversions.

The remainder of the tributary streams of the Darling traverse the artesian area, the country becoming rapidly less arid in an easterly direction, and increasing in aridity to the west. The works constructed up to the present on the easterly stream consist of diversions from the main into effluent channels for stock purposes; the surplus water in every case flowing into the Barwon. These works consist of a cutting from the Big River into the Meei, viâ the Greenbah Creek, a cutting from the Meei into the Moomin Creek with a weir in the Meei. It is proposed, in addition, to make a cutting at the bifurcation of the Meei and Big River. A cutting from the Big River into the Carore Creek, a cutting from the Moomin into the Thalaba Creek, a cutting from the Namoi into the Gunidgera and Pian Creeks, with a weir in the Namoi below Wee Waa. When stock purposes have been served, the remainder of the flow

of these streams should be reserved for the use of the Lower Darling where the aridity is much greater, and any irrigation over this area should be from artesian bores, if the supply from such is sufficient and can be economically applied.

No works have been constructed on the tributary streams or to west of the Darling, and no facilities exist for diversions; they are more intermittent in flow than those on the eastern side and the only means of utilising them is by means of weirs for stock purposes. These streams are so intermittent in flow and the facilities for large storage wanting, that irrigation from them is not practicable, and they are for the same reason of doubtful utility for stock purposes. The artesian supplies must therefore be mainly depended on over this area for all purposes.

Artesian Area.—The artesian area in New South Wales physically and climatically closely resembles the portion of the Darling watershed in the same State. The sources of supply of both are the western slopes of the Dividing Range in this State, the average rainfall decreasing in like manner as each recedes from its source. It has been stated previously that with regard to the rivers of this State, the records of the department enable a close estimate to be arrived at of the quantity of water available in average and dry seasons. As regards the artesian supply there is no reliable information on this point, although estimates varying in amount have been made on different bases by several people. It is absolutely necessary to deal comprehensively with a system of water conservation that this should be obtained, and as it is probable that the whole of the area in this State receives its supply from sources within this State, this information can be obtained without the co-operation of neighbouring States. The first information required is a detail geological survey to define the

extent of the intake beds, an analysis of their porosity, and careful measurements of the streams crossing them. The discharges and pressure of all Government, and, if possible, private bores should be taken from time to time, and their history recorded. It has been found in Queensland, where a good deal of attention has been devoted to like investigation, that the bores as a whole are decreasing in flow; we are quite in the dark as to what is taking place in this State, and it may be said we have practically no information on the subject.

In addition to this, in the rolling country west of the Darling, a few lines of levels might be run out along the main stock routes and the artesian water levels picked up to enable bores to be located in the best positions, and so that it can be estimated with some degree of certainty whether supplies will be artesian or sub-artesian; and an approximate idea obtained of the probable flow.

It must be recognised that there is a limit to artesian supplies equally with surface supplies, their sources being the same, namely, the rainfall. The total artesian area in New South Wales is 83,000 square miles, and includes the most arid portion of the State as well as a portion with a fairly high average rainfall; the largest flows are obtained at the least cost on the eastern side of the Darling, where the rainfall is greatest, while in the western bed in the more arid portion the supplies are smaller and more scarce.

The amount of water at the present time diverted from the artesian flow, both by private and Government bores, is undoubtedly well within the limits of the average yearly intake; but it must be recognised that the day will come when the limits will be reached, and the information necessary for the apportioning the supply to the semi-arid, arid, and very arid areas should be obtained as soon as possible. This question is one of much greater complica-

tion than dealing with the surface waters. Great waste of water has occurred in the past group of bores.

The most arid area lies west of the Darling, is under the jurisdiction of the Western Land Board, and consists almost entirely of Crown lands. The Western Land Board consider that the long tenure of lease and security of tenure provided under the Western Lands Act will be sufficient inducement for pastoralists to sink bores themselves; but there is still scope for a large expenditure by the Government in the provision of water on travelling stock routes, and in defining the boundaries of the artesian area by experimental boring. As has been pointed out, it is to the interests of the whole State that the whole of the lands should be under occupation, and it is by this means that the occupation of the western lands can be made profitable. The necessity for additional water on some of the stock routes was strongly pointed out in evidence before the Royal Commission of the Western Lands, and the exploration of the artesian boundaries cannot be undertaken by private individuals, and is within the functions of the State. The Western Land Act provides for the re-appraisement of lease where an increment in value has accrued from the construction of a public work, so that where such bores are successful a return is always obtainable.

Harbour Works, N. S. Wales.—Mr. T. Keele, M. Inst. C.E., Engineer for Harbours, has supplied the following information:—The Coastal Division, owing to its favourable conditions as to soil and climate, admits of much closer settlement than other portions of New South Wales, and even at the present time about $\frac{4}{7}$ths of the total number of persons employed in rural occupations are to be found in the coastal area. The rivers are the natural highways of the districts through which they pass, and as there can

be little development unless access to the metropolitan markets is rendered both cheap and easy, it is essential if the best is to be made of the river districts that these highways should be improved and maintained.

During the past ten years, over five millions sterling have been expended in the construction of breakwaters, training walls, dredging, reclamations, snagging, wharfage, docks, and other works for the maintenance of navigation. Of this sum about one and a half millions have been spent on dredging.

The main principle adopted for the permanent improvement of the river entrances, namely, concentrated tidal scour by the construction of breakwaters and training walls has been eminently successful, and must eventually lead to a large reduction in the cost of dredging in the lower and unstable portions of the rivers, and enable the dredge plant to be utilised in deepening the upper parts, and greatly extending the limits of navigation.

All the schemes now under construction for the improvement of the various river entrances have been commenced during the past ten years, with the exception of those at the Richmond, which were started in 1889. The following is a list of the harbour entrance works partially constructed: Tweed, Richmond, Clarence, Bellinger, Nambucca, Macleay, Hastings, Camden Haven, Manning, Cape Hawke, Newcastle, Port Kembla, Crookhaven, Bateman's Bay, and Moruya. Of these, three are in accordance with the designs of the late Sir John Coode, with some modifications, the remainder being those of the Harbours and Rivers Branch. In the report of the Principal Engineer for Harbours and Rivers for the year 1901-2, will be found particulars of the improvements in the lower channels, which have been brought about by the construction of training walls, assisted in some cases by dredging. Information

will also be found as to the distances of the quarries from the works, method of conveying stone, and cost per ton in place, quantity and cost of various materials dredged, etc.

Sewerage System.—In sewerage construction, the question of excluding rainfall or admitting a certain portion of it into the sewers, as in the so-called combined and separate systems, the results of experience up to date, according to Mr. Rudolph Herring, M. Am. Soc. C.E., M. Inst. C.E., appear to be as follows:—

The combined system is preferable:

Where rain water must be carried underground from extensive districts, especially where closely-built upon, and where new sewers must be built for this purpose.

Where purification is not required, or is not difficult, and where storm water overflows are not objectionable in polluting the streams.

Where a sufficient amount of water or sewerage is available for flushing the larger sewers.

The separate system is preferable:

Where rain does not require extensive underground removal.

Where an existing system of old sewers which cannot be made available for the proper conveyance of sewage can yet be used for storm water removal.

Where purification is expensive, and where storm water overflows would become objectionable.

Where pumping of sewage is too expensive to admit the increased flow from interceptors during rain.

Where it is necessary to built a system of sewers for house drainage at the least possible cost and delay, and where the underground rain water removal can be postponed.

Sewage Disposal.—The most recent improvement in this direction is the introduction of the septic tank by Cameron at Exeter, England, in 1896, which proved that a closed tank, through which sewage passed slowly, was a means by which not only the amount of suspended organic matter in sewage could be greatly reduced, but a partial purification of the sewage brought about. Experimental septic tanks were afterwards built in many places in England—first closed tanks similar to the one at Exeter, then open tanks, and to-day septic tanks, closed or open, are recognised as an essential part of modern bacterial purification processes. An excellent report on this subject has been recently published by the Government Printer, namely: "Report on the latest methods in use in the United Kingdom and elsewhere on Sewage Purification and Disposal," by J. Davis, M. Inst. C.E., Under-Secretary for Public Works, formerly Engineer-in-Chief for Sewerage Construction.

In nearly every case the septic tank is a valuable adjunct to the method of intermittent filtration and an essential adjunct in the methods of treatment by contact beds and percolating filters.

New South Wales Government Railways.—The most important works carried out in connection with the Permanent Way Department of the Railways may be summarised as comprising improvements of grades and curves; duplication of existing lines; strengthening of existing lines; strengthening of old bridges; the provision of new buildings for locomotive and traffic purposes, and the provision of extensive water supplies to meet increasing consumption of water by the Locomotive Department.

Improvement of Grades and Curves.—In regard to improvement of grades the practice has been to deal with such steep grades as ruled, the loads that could be hauled

by a single locomotive over a comparatively long mileage, provided those grades could be so improved as to permit of a considerably increased load for a long haul, at a cost on which the interest would be appreciably less than the working expenses entailed by carrying much smaller loads. As instances, it may be mentioned that the load for all trains between Hill Top and Goulburn was ruled by a number of heavy grades varying from 1 in 30 to 1 in 40, and these existed at eleven points in a distance of 65½ miles, and only in one case was the ruling grade over a mile in length, so that about nine miles of heavy gradient ruled the load over a total distance of 65½ miles. Again, between Goulburn and Cullerin five short grades of 1 in 40 existed which ruled the load for one engine, or demanded the use of an assisting engine over a length of 20 miles. On examination it was found that the cost of the alteration would be so small, that the reduction in working expenses would pay a considerable interest on the outlay involved in the work, the effect of which would be that loads could be drawn over practically any other part of the section unassisted, could be taken right through the whole section without the use of an assistant engine. The same principle applies practically to the whole of the grade alterations which have been carried out on the main Southern, South-Western, main Northern, North Coast and North-Western lines.

The practical value of these works may be realised when it is stated that, on the Southern line, a full load of forty-five wagons can now be taken over the whole section between Junee and Harden, and between Cullerin and Sydney, as against a load of about twenty wagons that could be previously taken. On the main Western line the works carried out permit of a full load of forty-five wagons being taken from Narromine to Wellington, a distance of

52 miles; from Mullion Creek to Tarana (83 miles) and from Clarence Siding to Sydney (88 miles). The sections between Wellington and Mullion Creek (45 miles) and Tarana to Clarence Siding (32 miles) still contain steep grades which have not yet been improved, owing to the large expenditure involved; but before the alterations already carried out, the load would practically have been limited to thirty wagons over the whole distance, or two engines would have been required on every goods train. On the North-Western, Northern, and North Coast lines the continuous improvements of grades carried out have had the effect of raising the through load from Moree to Sydney (413 miles) from a gross tonnage of 270 tons to about 430 tons, the whole journey being now accomplished without an assisting engine, except over the section between Murrurundi and Willow Tree (15 miles), and from the Hawkesbury River to the top of the bank, a distance of about five miles, to cut out which would entail very heavy expenditure. On these particular gradients it is found to be more economical to utilise the assistance of what is called a "push-up" engine. A total amount of £750,000 has been expended by the Commissioners on these important works.

Duplication.—It has been found necessary to duplicate portions of the lines, owing to the traffic having increased to such an extent as to be beyond the economical carrying capacity of a single line. The most important work within recent years has been the duplicating of the line between Glenbrook and Mount Victoria on the main Western line, and between St. Leonards and Lindfield on the North Shore line. In an ordinary way it is not expected to reap interest on the actual outlay in the case of duplications, but, as a matter of fact, the interest on the expenditure is practically saved by the reduction in salaries to officers

required to take charge of loops on single lines, and in the saving effected by reducing the amount of detention to trains crossing one another at these crossing loops. A total expenditure of nearly £250,000 has been expended during recent years in duplication works.

Strengthening Lines.—In order that the advantages of railway communication might be afforded to outlying districts, the Commissioners some years ago decided that it would be desirable to construct new lines in such districts in as cheap a manner as possible, strengthening them subsequently as the traffic developed. The Corowa line and the line between Molong and Forbes were originally constructed as light ones with 60 lb. rails, on sleepers 8 feet by 9 inches by 4½ inches, spaced about 2 feet 10 inches centres, bedded upon 4 inches of broken stone ballast, and boxed up with the same material. The growth of traffic, owing to the opening up of the country for agriculture, necessitated the use of heavy engines for economical working, and it therefore became necessary to strengthen the permanent way by the provision of additional sleepers. This was done, and the sleepers re-spaced about 2 feet 2 inches centres, the result being most satisfactory; the lines, with the additional support, being rather more easily maintained than before, even with engines of the heaviest class working over them.

Bridges.—When the first lines were constructed, locomotives were much lighter than at the present time, and the iron bridges then erected were designed to give a sufficient factor of safety for the heaviest load that could be applied by engines then in use. The weight of engines having practically doubled, however, it was necessary some few years back to strengthen a number of the old iron bridges, notably those over the Wollondilly River on the main Southern line and over Solitary Creek on the

main Western line. The original structures were through bridges with plate girders, and both the main and cross girders were found to be rather weak for the loads imposed by the heaviest classes of the new engines. The method of strengthening adopted was the insertion under the centre of the cross girders of a new main girder, designed practically to carry the whole of the load imposed on the bridge, and of course by giving the support to the cross girders at the centre they were strengthened at the same time.

Another important bridge work was the renewal of the Wagga Wagga viaduct, originally a timber structure with 29 feet 6 inches spans. The same span was adopted in the new structure, light plate girder taking the place of the timber superstructure and steel trestles on concrete replacing the timber pile piers. Some 1,700 tons of steel were used in the work, which has been of great advantage both to the Permanent Way and Traffic Branches. To the former by doing away with the heavy annual maintenance cost of the old viaduct, and to the latter by enabling the heaviest classes of engines to be used over the section Junee and Albury, effecting a considerable annual saving in the train mileage.

Buildings.—With the growth of traffic, additional accommodation is constantly being provided, and for traffic purposes the largest works carried out for some years past have been a new outwards goods shed at Darling Harbour, 1,000 feet long by 90 feet wide. The shed is fitted with hydraulic cranes for quickly handling large packages, and about 100 trucks can be loaded at one time under cover. At Darling Harbour, in anticipation of a grain export trade, a large shed, about 1,100 feet long by 80 feet wide, and capable of holding some 30,000 tons of grain, was erected close to the main wharf. Three vessels can berth

at a time opposite this shed, which is fitted with lifting and conveying machinery operated electrically, so that the bags of wheat as they are brought in in the trucks can be distributed to any portion of the shed without handling, or can be conveyed direct through the shed and placed on board at a minimum of cost. The grain elevators provided each have a capacity to deal with 60 tons of grain per hour, and if the whole number were operating, about 400 tons an hour could be delivered on board the vessels lying at the wharf.

Other large building works carried out by the Permanent Way Branch in recent years are the new foundry and erecting shop at Eveleigh and the Ultimo power-house.

Water Supply.—As the traffic increases the number of locomotives is correspondingly increased, and consequently in some places the water supplies have had to be augmented. At Harden, for instance, an earth dam with clay core has been constructed, capable of impounding 20,000,000 gallons of water, at a sufficient height to give a gravitation supply to the locomotive depôt. At Wentworth Falls a large reservoir is also being provided by the construction of a dam, which will impound about 40,000,000 gallons and give a gravitation supply for the watering stations at Wentworth Falls and Lawson.

Locomotive Branch.—In the Locomotive Branch many improvements have been introduced by the Commissioners in the character of the rolling stock. Soon after their appointment, the demands of the traffic pointed out to them the advisability of introducing more powerful locomotives for the economical working of the long single lines in this State, with their heavy grades and sharp curves, and so increasing the weight of trains and reducing the train mileage. With this object, powerful engines suitable for meeting the requirements, were designed specially for heavy express

passenger service, so that time might be saved in climbing the numerous banks. Fifty of these engines—known as the "P" class—were obtained on the first order in 1891, and found so suitable for the work that subsequent orders were given. They are of the six-wheel coupled type, with a four-wheel bogie at the leading end, embodying the general features of English practice in detail and general construction. The cylinders are placed outside the frames, with the steam chests and ports between them, fitted with balanced slide valves operated by Allen's straight link motion and controlled by screw reversing gear. The boilers are of the Belpaire type, constructed of steel plates, with fire-boxes and tubes of copper. Both engine and tender are thoroughly equipped with Westinghouse automatic brake and screw hand-brake gear, and every provision has been made for large and efficient wearing surfaces. They are provided with the most modern means and appliances for the purpose of lubricating all moving parts and the wearing surfaces are protected, where possible, from dust. Steam sanding gear is applied to the engines and ordinary hand sand gear to the tenders.

For similar reasons, it was found desirable to design engines suitable for effectually meeting the goods traffic. A very powerful class was first put into service in May 1896, known as the "T" class, and there are now 85 of them in traffic. In design they embody the general features of English and American practice, known as the eight-wheel coupled or "consolidation" type, with a single axle Bissel truck at the leading end. The cylinders are placed outside the frames, with the steam chests and ports between them, fitted with balanced, tripp-ported, slide valves, operated by Allen's straight link motion, and controlled by screw reversing gear. Thirty-five of the engines are equipped with cylindrical piston valves for the purpose of

experiment. The boilers are similar in all respects but larger than those for the passenger engines.

The tenders are carried on double bogie trucks, necessitated by the large capacity and sharpness of many of the curves on the mountain lines of these railways. Both engine and tender are thoroughly equipped with Westinghouse automatic and hand screw brake-gear, and every provision has been made for large and efficient wearing surfaces, dust shields and lubricating appliances.

The class of engine used in the suburban passenger service has also been improved by the Commissioners, and 15 engines of what is known as the "M" class, commenced service in 1891. They are of the four-wheel coupled type, and a four-wheel bogie at the front end and single radial axle at the rear end.

Owing to the heavy passenger traffic that has now to be carried over the suburban lines during the busy hours of the morning and evening, it is considered advisable to run trains longer than those hauled by the present "M" class engines, and therefore a more powerful suburban tank engine is now being delivered on order. They will be known as the "S" class, and be capable of hauling at least 25% more load than has previously been dealt with. They have outside cylinders fitted with balanced slide valves, operated by Allen's straight link motion, controlled by screw reversing gear. The boilers are similar in design, and constructed of the same class of materials as those for the passenger and heavy goods engines. Side tanks and coal bunkers are arranged with gangways for access to the enginemen's platform in the same way as the "M" class. The following schedule gives the main dimensions of the four modern engines above alluded to :—

ENGINES.	"P" Class Heavy Express Passenger.		"T" Class Heavy Goods	"M" Class Suburban Tank	"S" Class Heavy Surburban Tank.
	ft. in.		ft. in.	ft. in.	ft. in.
Cylinders, dia.	1 8		1 9	1 5	1 6½
„ stroke	2 2		2 2	2 2	2 0
Bogie wheels, diam.	3 3		2 9½	3 3 front	3 1
Coupled wheels, diam.	5 0		4 3	4 0½ hind	4 7
Bogie wheel base	7 0		...	5 1	6 2 front
Rigid „ „	13 10		15 0	6 6	5 6 hind
Total „ „	25 0		23 2	8 8	10 9
„ „ „ engine and tender ...	51 2¾ Bogie tender 46 10 6-wheel tender		51 10¾	28 11	32 3
Boiler presure	160 lb.		160 lb.	160 lb.	160 lb.
Grate area ...	27 sq. ft.		29·75 sq. ft.	18·75 sq. ft.	24 sq. ft.
Heating surface	1,916 ft.		2198 „	1221 „	1456 sq. ft.
TENDERS.	6-wheel tenders.	Bogie tenders.			
Wheels, diam.	3 ft. 7¼ in.	3 ft. 1 in.	3 ft. 1 in.		
Wheel base ...	12 ft.	16 ft.	16 ft.	Tanks.	Tanks.
Water capacity	3030 gal.	3650 gal.	3650 gal.	1200 gallons	1580 gallons
Fuel „	4½ tons	6 tons	6 tons	2½ tons.	2½ tons
Weight of engine in working order ...	t. c. q. 56 10 3	t. c. q. 56 10 3	t. c. q. 65 15 0		
Ditto, tender ...	31 16 1	41 10 0	41 10 0		
Total weight in working order	88 7 0	98 0 3	107 5 0	56½ tons	(approx.) 72½ tons

In the passenger rolling-stock, the principal innovation in recent years has been the introduction of the corridor carriages. These are long vehicles carried on six-wheeled bogies, constructed with end platforms and doors entering into side corridors. The side corridors communicate with the separate compartments into which each vehicle is divided. Each compartment in the first-class is upholstered in white figured fibre cloth, neatly decorated, and arranged to seat six passengers. The compartments of the second-class are upholstered in leather, and seat eight passengers in each. For both classes, separate lavatory accommodation, smoking and ladies' sections are provided. The external appearance of the cars is the same, but internally the compartments are fitted up suitably for first and second-class passengers. The cars are of a uniform length of 61

feet over panels, and 9 feet 4¼ inches wide over panels. They have been all built in the railway workshops at Eveleigh. In addition to the corridor cars, there have also been built in the railway shops a number of sleeping cars. Long cars, for first-class passengers, and carried on six-wheeled bogies, have been built on both the "Pullman" and "Mann" systems for Inter-State trains. Shorter sleeping cars of the "Pullman" type, arranged in every respect like the longer "Pullman" vehicles but carried on four-wheeled bogies, have been built for the shorter distance first-class passengers. The "Pullman" vehicles are arranged with end platforms and doors which communicate by a central passage, with upper and lower berths on each side of the car arranged longitudinally in the usual way. The cars on the "Mann" system have similar end platforms and doors, but communicate by a side corridor with separate compartments or cabins fitted with upper and lower berths arranged transversely. The long vehicles of all kinds, both sleeper and non-sleeper, used for Inter-State traffic, are fitted with vestibule end passages which permit through communication from end to end of the train. Brake and parcel vans, post-office vans and mail baggage vans to match the above mentioned vehicles have also been constructed to run with each train.

In regard to the merchandise stock a number of refrigerator cars have been constructed for the conveyance of dead meat and other perishable products from the interior to the seaboard. The old style of goods wagon with small carrying capacity has been largely replaced by vehicles with composite or steel frames, having a carrying capacity of 10 and 15 tons; while a large number of 15-ton wagons, constructed entirely of pressed steel have lately been added to the stock.

In order to cope with the increasing amount of work, it was found necessary in 1899, to put up new erecting shops

of modern design to meet repairs of the heavier types of locomotives introduced, and four electric, overhead, travelling cranes are installed in them. Each crane lifts and travels a safe working load of 35 tons, operated by separate shunt-wound motors under a current of 500 volts, and capable of moving the cranes at a speed of 200 feet per minute along the shop, cross-travelling the crab at 60 feet per minute, lifting light weights at 24 feet and under, and heaviest loads at $2\frac{5}{8}$ feet per minute. The different motions are controlled by suitable handles, arranged in the driver's cage attached to each crane. The machinery in these shops, such as lathes, drills, shapers, etc., is driven by an electric motor, connected by belting to the main line shafting which runs down the centre of the building. This installation having proved successful in every way, it was decided to convert five of the heavy, older, rope-driven overhead travelling cranes in use, into electric cranes, a change which has made them much more lively and useful.

In addition to these, several heavy modern machines are provided with and driven by independent electric motors, such as powerful multiple drilling machines, milling machine and circular saw for the purpose of dealing with boiler plates, heavy bars etc. Electric driving is also used for two ground traversers of 60 feet length, in the carriage and wagon shops, which are powerful, active machines. The electricity used for driving the cranes and machines is obtained from the tramway power-house at Ultimo.

A very complete installation of compressed air machinery and appliances was introduced in 1899, so as to secure the economy of using portable drills, boring tools, caulking tools, small riveting machines, lifting appliances, etc., specially made for compressed air, instead of the old hand-labour methods. Compressed air is also used for re-boring locomotive cylinders and driving small forging machines.

These special hand-labour saving appliances have materially increased the economy and output of the workshops.

* * *

I have endeavoured to indicate in this address some of the achievements of the engineer during the last twenty years. The wonderful progress during that time, and the great activity to-day in all branches of science and engineering suggest gigantic possibilities in the future. All future progress in engineering must depend upon exact knowledge and scientific thought and work. Our systems of primary, secondary, technical and professional education must be carefully reconsidered in order to bring them up to the needs and requirements of modern civilization. The engineer of the future must be a still more widely trained and better educated man than his predecessor of to-day, so that he may be better able to solve the many problems which lie before him in the future.

I will now bring this long address to a close by thanking you for the patient attention with which you have listened to it, and in vacating the Chair in favour of Mr. F. B. Guthrie, the newly elected President, I ask you to give him the same support which has always been accorded to me.

LANGUAGE OF THE BUNGANDITY TRIBE, SOUTH AUSTRALIA.

By R. H. MATHEWS, L.S.,
Associé étranger Soc. d'Anthrop. de Paris.

[*Read before the Royal Society of N. S. Wales, June 3, 1903.*]

SYNOPSIS—Prefatory. Orthography. Grammar of the Būngandity Language. Vocabulary.

THE Būngandity tribe occupied the country around Mount Gambier, County of Grey, South Australia, and extended easterly into Victoria as far as the valley of the Glenelg River. This tribe was typical in language, customs and social organisation, of an aggregate of about half-a-dozen small tribes, the limits of whose territory may be indicated approximately by a line drawn from Kingston to Bordertown, and thence southerly to the sea coast. Having on different occasions during recent years visited this part of South Australia and the adjacent portion of Victoria, I had the good fortune to find a few surviving members of the Būngandity tribe, from whom I obtained the materials of the present treatise.

It has fallen to my lot to be the first author to investigate the constitution of the Būngandity language and supply the elements of its grammar. The whole of this article has been prepared by me from notes taken down by myself from the lips of the aboriginal speakers, and I am alone responsible for the information contained. When the difficulties encountered in obtaining the grammar of any language which is purely colloquial are taken into consideration, I feel sure that all necessary allowances will be made for any imperfections of my work.

In the Būngandity language, inflection for person and number is not confined to the verbs and pronouns, but extends to many of the nouns, adjectives, prepositions, adverbs and interjections, a peculiarity which was reported in detail by me in certain aboriginal tongues of New South Wales,[1] Victoria,[2] and Queensland.[3]

A feature of the genitive case in the Būngandity tongue, not reported by any previous writer as existing in the aboriginal languages of South Australia, is that the proprietor and the property both take a possessive affix. I was likewise the first author to report a similar double form of the genitive case in the languages of New South Wales,[4] and Victoria.[5]

In every part of speech subject to inflection in this language, there are two forms of the first person of the dual, trial, and plural, one of which includes, and the other excludes, the individual who is spoken to. This peculiarity has not hitherto been reported in any of the native languages of South Australia.

In consequence of my visit through the territory of the Būngandity people and their congeners in 1898, I contributed to the Anthropological Society at Washington, an article dealing with their social organisation and initiation ceremonies,[6] for particulars of which the reader is referred to the publication in question.

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[1] "Thurrawal, Gundungurra and Dharruk Languages,"—Journ. Roy. Soc. N. S. Wales, xxxv., pp. 127 - 160.

[2] "The Aboriginal Languages of Victoria,"—Journ. Roy. Soc. N. S. Wales, xxxvi., pp. 71 - 106.

[3] "Languages of Some Native Tribes of Queensland, etc."—Journ. Roy. Soc. N. S. Wales, xxxvi., pp. 135 - 190.

[4] Proc. Amer. Philos. Soc., Philadelphia, xl., p. 143.

[5] Journ. Roy. Soc. N. S. Wales, xxxvi., p. 78.

[6] "The Victorian Aborigines—their Initiation Ceremonies and Divisional Systems,"—American Anthropologist, xi., pp. 331 - 336, with map of Victoria.

In 1880, Mrs. James Smith published a vocabulary and a few fragments of grammatical rules of the language of this tribe, whose name she erroneously gave as Booandik.[1] Mr. E. M. Curr, in 1886, also published a short vocabulary of this language,[2] but its grammatical structure was left untouched.

In a sentence the subject is usually placed first, then the direct object, and the verb last. The indirect object often follows the verb. An adjective qualifying either the nominative or objective, follows the noun. An interrogative sentence does not differ in form from an assertive one, the distinction being indicated by the tone and accentuation of the speaker's voice.

It should be stated that in all the expressions illustrating the several cases of nouns in this article, the demonstrative pronouns are purposely omitted, for the two-fold purpose of saving space, and of avoiding confusion by introducing any more words than are really required to exhibit the declension. We will take an example from the instrumental case of nouns, where I have said, "a man beat a dog with a boomerang." This would be expressed by a blackfellow something as follows:—"This-in-front man beat yonder-in-the-rear dog with that-over-there boomerang." or such other demonstratives as the subject might require.

All the South Australian tribes about Lake Eyre, Oodnadatta, Alton Downs, and Innamincka, and thence southerly over all the intervening country to Port Lincoln and Mount Gambier, are divided into two phratries—the men of each phratry marrying the women of the opposite one. In some districts these two phratry names are Kurogity and

[1] "The Booandik Tribe of South Australian Aborigines," (Adelaide, 1880).

[2] "The Australian Race," III., pp. 462 – 465.

Kamaty, in others Matturri and Kirraru, in others they are Kulpirro and Thinnawa, and again in others Kukudyiba and Kuchibinga. For particulars of these systems of intermarriage, and the laws regulating the descent of the offspring, the reader is referred to an article I communicated to the American Philosophical Society at Philadelphia, U.S.A., in 1900.[1] The boundaries which separate the tribes who practise circumcision, and splitting the male urethra, from those tribes among whom neither custom is in force, is described in the article referred to, and delineated upon an accompanying map of South Australia.

Within the geographic limits mentioned in the preceding paragraph, the grammatical structure of the native tongues in its fundamental principles closely resembles that of the Būngandity language. From enquiries I have made it is found that the cases of nouns and their qualifying adjectives are declined by similar postfixes. That in all parts of speech subject to inflection, there is an inclusive and exclusive form of the first person in the dual and plural numbers. An abbreviated form of the pronoun is affixed to the root of the verb to indicate number and person. In the genitive case of nouns the property and the owner are both inflected.

Friends who have visited Alice Springs and Arltunga during the last couple of years, to whom I had previously submitted a number of questions for investigation, inform me that the double form in the dual and plural of the first person, to include or exclude the party addressed, is persistent in all the languages of the native tribes from Alice Springs along the overland telegraph line to Port Darwin,

[1] "Divisions of the South Australian Aborigines,"—Proc. Amer. Philos. Soc., Vol. xxxix., pp. 78 - 93, with map of South Australia. It may be mentioned here that I was the first author to discover and report the existence of the phratries Kulpirro and Thinnawa, and also Kukutyiba and Kuchibinga above referred to.

reaching thence easterly into Queensland,[1] and also westerly into West Australia.

ORTHOGRAPHY.

Eighteen letters of the English alphabet are sounded, comprising thirteen consonants—*b*, *d*, *g*, *h*, *k*, *l*, *m*, *n*, *p*, *r*, *t*, *w*, *y*—and five vowels—*a*, *e*, *i*, *o*, *u*.

The system of orthoepy adopted is that recommended by the circular issued by the Royal Geographical Society, London, with the following qualifications:—

It is frequently difficult to distinguish between the short sound of *a* and *u*. A thick sound of *i* is occasionally met with, which closely resembles the short sound of *u* or *a*.

As far as possible, vowels are unmarked, but in some instances the long sound of *a*, *e*, and *u* are indicated thus, ā, ē, ū. In a few cases the short sound of *u* has been marked thus, ŭ.

G is hard in all cases. *R* has a rough, trilled sound, as in hurrah! *W* always commences a syllable or word.

Ng at the beginning of a word or syllable as *ngu* in *ngu-ro*, thou, has a peculiar sound, which can be got very closely by putting *u* before it, as *ungu'*, and then articulating it as one syllable. At the end of a syllable it has substantially the sound of *ng* in "sing."

The sound of the Spanish ñ is frequent; at the beginning of a word or syllable I have given it as *ny*, but when terminating a word the Spanish letter is used. *Y* at the beginning of a word or syllable has its ordinary consonant value.

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[1] See my "Yualeai and Pikumbil Languages,"—Journ. Roy. Soc. N.S. Wales, Vol. XXXVI., pp. 137 - 145. Also my "Murawarri Language,"—Queensland Geographical Journal, Vol. XVIII., pp. 52 - 68. These three languages are spoken in Queensland.

Dh is pronounced nearly as *th* in "that," with a slight sound of *d* preceding it. *Nh* has also nearly the sound of *th* in "that," but with an initial sound of the *n*. A final *h* is guttural, resembling *ch* in the German word joch.

T is interchangeable with *d*, *p* with *b*, and *g* with *k*, in most words where these letters are employed. *Ty* and *dy* at the commencement of a word or syllable have nearly the sound of *j* or *ch*, thus *dya* or *tya* closely resemble *ja* or *cha*. At the end of a word or syllable, *ty* or *dy* is sounded as one letter; thus *dity*, the last syllable of Bŭng-an-dity, can be pronounced exactly by assuming *e* to be added to the *y*, making it dit-ye; then commence articulating the word, including the *y*, but stopping short without sounding the added *e*. *Dy* at the end of a word can be pronounced in the same way, the sound of *d* being substituted for that of *t*. In all cases where there is a double consonant, each letter is distinctly enunciated.

The Bungandity Grammar.

Articles.

The place of the English article is supplied by various forms of the demonstratives representing "this" and "that," which are declinable like the noun. If it be desired to definitely say that only one object is meant, the numeral, wandho, one, would be employed.

Nouns.

Number—Nouns have the singular, dual, trial and plural. Drual, a man. Drualara, a couple of men. Drualwawung, three men. Drualabañ, several men.

Gender—Drual, a man. Bulle-bulle, a woman. Murungal, a boy. Barraty, a girl. Among animals sex is distinguished by words meaning "male" and "female," respectively, thus, guramu mamung, a buck opossum. Guramu ngurtung, a doe opossum.

Case.—To form the cases, nouns take additions by means of postfixes:

Nominative—This case merely names the thing spoken of, and is without flexion, as, gal, a dog; gettup-gettup, a boomerang; gurē, a kangaroo; kanna, a yamstick; wiriñ, a waddy.

The causative, or nominative-agent, represents the subject doing some act, as Drualla gal winan, a man a dog beat. Gala guramu ngutthan, a dog an opossum bit.

Instrumental.—This case takes the same affix as the causative. Drualla gal winan gettup-gettupa, a man beat a dog with a boomerang. Bulle-bullā murungal winan wirinya, a woman beat a boy with a waddy. Sometimes, in such expressions as these, the causative suffix is omitted, and the instrumental only employed.

Genitive.—The owner and the chattel are both declined, but the affix to the former differs from that to the latter:[1] Drualangat gettup-gettupmung, a man's boomerang. Bulle-bullangat kannawung, a woman's yamstick.

Personal property of any description can be declined by possesive suffixes to the noun, thus:

Singular	1st Person	Gettup-gettupmain,	My boomerang
	2nd „	Gettup-gettupmun,	Thy boomerang
	3rd „	Gettup-gettupmung,	His boomerang

and so on through the remaining numbers.

If two or more articles be claimed, an infix is inserted between the noun root and the possessive affix, thus:

Dual	Galaramain,	My two dogs
Trial	Galawawungain,	My three dogs
Plural	Galabañain,	My several dogs.

[1] See my "Thurrumba Language,"—Queensland Geographical Journal, Vol. XVIII., pp. 58 - 61,

Another way of expressing ownership of two or more articles is to annex the suffix of number to the name of the thing possessed, and then use the possessive pronoun, as Galara ngatthowat, dogs two mine. Galabañ ngatthowat, dogs several mine, and so on. The accusative is the same as the nominative. The other cases are omitted in this paper.

ADJECTIVES.

Adjectives are placed after the nouns they qualify, and are similarly declined for number and case. They are compared by making two positive statements, such as, "this is large—that is small."

There are euphonic modifications of the suffixes in the declension of all the cases of nouns, and also of the qualifying adjectives, depending upon the termination of the word declined. Occasionally the suffix of the noun is left out—at other times that of the adjective—being regulated by the euphony of the expression. Certain adjectives, when used predicatively, admit of inflection as intransitive verbs.

PRONOUNS.

Pronouns have number person and case as in the following table. There are inclusive and exclusive forms for the dual, trial and plural of the third person, as shown in the table below. The trial forms of the pronouns, and also of the verbs, are obtained by adding the word *wawung* to the plural, in the same way that *baiap* and *kullik* are employed in other languages reported by me last year.[1]

With the exception of a few remarks by myself,[2] no previous author has discovered the existence of the trial number in any part of speech in the languages of South Australia.

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[1] "The Aboriginal Languages of Victoria,"—Journ. Roy. Soc., N. S. Wales, XXXVI., p. 74.

[2] "The Wuttyubullak Language,"—Queensland Geographical Journal XVIII., p. 61.

The following table exhibits the nominative pronouns:—

Singular	1st Person	I,	Ngattho
	2nd ,,	Thou,	Nguro
	3rd ,,	He,	Nuang
Dual	1st Person	We, incl.,	Ngatthohal
		We, excl.,	Natthowillal
	2nd ,,	You,	Ngutpul
	3rd ,,	They,	Nunggul
Trial	1st Person	We, incl.,	Ngatthohēwawung
		We, excl.,	Ngatthowillēwawung
	2nd ,,	You,	Ngutpuerwawung
	3rd ,,	They,	Nungbawawung
Plural	1st Person	We, incl.,	Ngatthohē
		We, excl.,	Natthowillē
	2nd ,,	You,	Ngutpuer
	3rd ,,	They,	Nungba

The singular number of the possessive pronouns will show their formation:

Singular	1st Person	Mine,	Ngatthowat
	2nd ,,	Thine,	Ngatthowin
	3rd ,,	His,	Nuangat

Also see the possessive forms of the demonstrative pronouns further on.

The foregoing full forms of the pronouns are employed chiefly in answering questions. In ordinary conversation the natives use the pronominal affixes illustrated under the heading of "Verbs."

The objective pronouns, me, thee, him, etc., are not found separately, like the nominative and possessive, but consist of pronominal suffixes to verbs, nouns, or other parts of speech:

1st Person	(Someone)	speaks to me,	Lānandhanañ
2nd ,,	,,	speaks to thee,	Lānandhanun
3rd ,,	,,	speaks to him,	Lānandhawung

and so on for the other numbers. See also the example

under "Prepositions." There are forms of the pronouns meaning "with me," "towards me," "away from me," etc., and also causative forms, as Ngatthowir, I (did it).

Demonstratives.—The demonstratives in this language, by the combination of simple root-words, can be made to indicate distance, direction, position, size, number, person, possession, movement, etc. Only a few examples will be given at present:—This, nu. This perhaps, numiu. That, nuana. That (yonder), gwalluburu. That (person), 'dhaiu. That, (up there), gannu. That, (down there), wannu. This is mine, ngunnahain. This is thine, ngunnahun. This is his, ngunnahung. See also possessive affixes to nouns in an earlier page.

Many of the demonstratives are likewise used as pronouns of the third person, which explains the great number, irregularity, and lack of etymological connection found among such pronouns in the several aboriginal languages whose grammars I have promulgated. There are names for the different points of the compass, and a native will frequently indicate the position of anything by giving its compass direction from some well known tree or water-hole.

Interrogatives.—Who, ngānuin. Whose, ngānungat. What, nunh. What for, nunnagaŭ. How many, nuppur.

VERBS.

Verbs have the same numbers and persons, with inclusive and exclusive forms, as the pronouns. The principal moods are the indicative, imperative and conditional. Number and person are indicated by pronominal particles added to the verb stem, as exemplified in the conjugation of the verb "to speak."

Indicative Mood—Present Tense.

Singular	1st Person	I speak,	Lānha
	2nd "	Thou speakest,	Lānin
	3rd "	He speaks,	Lān

Dual	1st Person	We, incl., speak,	Lāngul
		We, excl., speak,	Lānga
Trial	1st Person	We, incl., speak,	Lānēwawung
		We, excl., speak,	Lānungēwawung
Plural	1st Person	We, incl., speak,	Lānē
		We, excl., speak,	Lānungē

In the above example, the whole of the singular, and the "double we" of the dual, trial and plural, have been given, omitting the second and third persons for want of space. In the past and future tenses, the singular number only will be illustrated:—

Past Tense.

Singular	1st Person	I spoke,	Lēanha
	2nd "	Thou spokest,	Lēanin
	3rd "	He spoke,	Lēan

Future Tense.

Singular	1st Person	I will speak,	Langunga
	2nd "	Thou wilt speak,	Langungin
	3rd "	He will speak,	Langu

Imperative Mood, Speak, Langga.

Conditional Mood, I will perhaps speak, Langungamiu.

Reflexive.

The reflexive form of the verb describes an action which the subject executes directly upon himself:—

I am talking to myself, Lānandhañ,

and so on through all the persons and numbers.

Reciprocal.

There is a form of the verb to express that two or more persons are reciprocally doing the act described:—

Dual—We are talking to each other, Lānandhawanul.

Trial—We are talking to each other, Lānandhawanēwawung

Plural—We are talking to each other, Lānandhawanē.

The second and third persons in each number are similarly inflected.

There are forms of the verb to indicate that the speaking was done just now, some time since, or long ago; that there was a repetition or a continuance of the speaking, and many other modifications which will be passed over.

There is no special form for the passive voice. The sentence, "a man was kicked by an emu," is expressed in Büngandity by the paraphrase, "an emu kicked a man."

Adverbs.

Yes, nguh. No, ngañ. To-day, kerdu. Yesterday, würdu. To-morrow, dēab. In a few days, dēaba. By and bye, gidho. Long ago, mangian. Where, na. Where is thy camp, na ngulangün. Certain adverbs can be declined for number and person. Where art thou, na-ungin. Where are you two, na-ungut, and so on.

Here, nu, There, nuana. Yonder gunnaua. "Here" and "there" have the meaning of "this" and "that," with which they are interchangeable.

Prepositions.

In front, kauiyung. Behind, wurdung. Other side, mianhung. This side, nuanhung. Between, brawōl. Up, kunmannha. Down, wiyua. Through, bureanha.

Many prepositions can be inflected for person and number thus: Behind me, wurdungañ. Behind thee, wurdungin. Behind him, wurdungung, and so on through all the numbers.

Interjections.

Kai! exclamation calling attention.

Numerals.

One, wandho. Two, bo-aty. Three, boaty-ba-wandho. Several, kullaity.

Vocabulary of Bungandity Words.

The following vocabulary contains about 245 of the most commonly used words in the Büngandity language, with their English equivalents. Every word has been noted

down carefully by myself from the old men and women in the native camps, and much time and care have been bestowed upon the work.

ENGLISH.	BUNGANDITY.	ENGLISH.	BUNGANDITY.
	The Family.		
A man,	drual	Mother,	ngāte
Husband,	marmbil	Single woman,	wiatgur
Father,	marm	Maid,	thutmirt
Initiated man,	bappŭtha	Girl,	barraty
Youth,	murungal	Elder sister,	tyatti
Boy,	kabunga	Younger sister,	nyuiyur
Elder brother,	wirraguli	Mother-in-law,	krinnung
Younger „	nyeri	Child, either sex,	bopop
A woman,	bulle-bulle	Child, crawling,	wimbungarn
Wife,	maha	Baby,	kongaparim
	Parts of the Body.		
Head,	bupe	Hand,	murra
Forehead,	ginne	Thigh,	gurrēp
Hair of Head,	ngulla	Knee,	parrañ
Beard,	ngullangunna	Foot,	dhinna
Eye,	mir	Blood,	kamar
Nose,	gāwu	Fat,	murnbui
Ear,	wah	Skin,	mūrn
Mouth,	lu	Bone,	bēh
Lips,	wuru	Penis,	wirranhung
Tongue,	dhē	Prepuce,	munaninyung
Teeth,	dhŭng-a	Scrotum,	burungan
Mammæ, female,	bāp	Pubic hair	ngullunhung
Umbilicus,	bi	Vulva,	ngunnunhung
Abdomen,	bui	Copulation,	dhanun
Back,	bunnu	Semen,	bullinyung
Heart,	lŭh	Anus,	mummung
Liver,	buth	Excrement,	gunanhung
Arm,	woañ	Urine,	thalubung
Shoulder,	wŭrt	Venereal,	wambañ
Elbow,	dhalin		

English.	Bungandity.	English.	Bungandity.
	Inanimate Nature.		
Sun,	kurru	Camp	ngulu
Moon,	dhunngam	Fire,	warnap
Stars,	dhumman-dhum- [man	Smoke,	buluñ
Thunder,	murndal	Food,	büngang
Lightning,	birdung-murndal	Day,	kurru
Rain,	gauañ	Dawn,	murrānan
Rainbow,	turāñ	Dusk,	müngiñ
Dew,	tharak	Night,	munginya
Frost,	wā-art	Morning,	kunyia kurru
Hail,	bāt	Evening,	kabinha kurru
Water,	purri	A splinter,	lirt
Stream,	wa-ün-purri	Leaves of trees,	yirra
Earth,	mirrēt	Egg,	kua
Stone,	murre	Honey,	minnhung
Sand,	mullang	Pathway,	warri
Hill,	bulity	Tail of animal,	wirra
Light,	yap	Shadow,	wül
Darkness,	mōl	Grass,	bürdu
Coldness,	mōt-mōt	Cave,	yulang
	Mammals.		
Dog,	gal	Grey kangaroo,	goañ
Wild Dog,	ganatyum	Porcupine,	willangga
Opossum,	guramu	Wombat,	morē
Native-cat,	gih	Bandicoot,	wian
Kangaroo,	gurē	Bat,	ngunnin-ngunnin
	Birds.		
Laughing Jackass,	gwaddung	Native Companion,	wandi
Crow,	wā	Black duck,	burnē
Plain turkey,	lah	Mopoke,	dhuni-dhunity
Pelican,	parangal	Plover,	püttherat
Swan,	gunawar	White cockatoo,	mā
Eaglehawk,	ngirri	Corella,	kurogity
Emu,	kauir	Lowrie parrot,	türt

Fishes.

English.	Bungandity.	English.	Bungandity.
Fish collectively,	tirto	Trout,	dŭrkŭrt
Eel,	guia		

Reptiles.

English.	Bungandity.	English.	Bungandity.
Ground iguana,	yuro	Carpet Snake,	binggal
Turtle,	turunggal	Frog,	dennab
Snakes collectively,	gurgang		

Invertebrates.

English.	Bungandity.	English.	Bungandity.
Blow-fly,	dhuratta	Bulldog ant,	mūn
House-fly,	yual	Maggot,	dhuratto
Louse,	mūrna	Leech,	dulung
Nit of louse,	guirung	Mussel,	wardarro
Jumper ant,	bitbitmula		

Trees and Plants.

English.	Bungandity.	English.	Bungandity.
Peppermint,	ngurrittha	White gum tree,	leng
She-oak,	ngering	Red gum tree,	bial
Tea-tree,	wiriu	Blackwood,	mura
Stringybark,	mirre	Ferns (bracken)	mē-e
Wattle,	kurra	Mushrooms, edible,	barringgut
Cherry tree,	tharam		

Weapons, Utensils, etc.

English.	Bungandity.	English.	Bungandity.
Tomahawk,	gŭrgañ	Waddy shield,	mulkar
Koolamin,	dhurung	Hunting club,	wiriñ
Yamstick,	kunna	Fighting club,	kunnāk
Jag spear,	kwiŭn	Head-band,	maragalañ
Reed spear,	dēr	Kilt,	kunal
Spear lever,	gumbañ	Net bag,	warak
Boomerang,	gettup-gettup	Canoe,	mirammun
Spear shield,	kirram		

Adjectives.

English.	Bungandity.	English.	Bungandity.
Alive,	yule	Strong,	binne
Dead,	nūan	Valiant,	mermeran
Large,	wurung	Afraid,	yinban
Small,	murugity	Right,	martŭng
Tall,	wurŭm	Wrong,	wīrang
Short,	mude	Tired,	thulban

English.	Bungandity.	English.	Bungandity.
Good,	martŭng	Sour,	gillat
Bad,	wĭrang	Sweet,	minnhung
Hungry,	dirtban	Warm,	bā-a-wan
Thirsty,	gurnanañ	Cold,	mudin
Red,	gannhurrung	Angry,	guli
White,	wadyunyea	Sleepy,	wity
Black,	wulu	Glad,	memmirun
Jealous,	mullaiammun	Sorry,	yerban
Quick,	binnangungea	Greedy,	ranglu
Slow,	beraŭngiñ	Sick,	gūnnguriñ
Blind,	munyiñ	Stinking,	bie
Deaf,	binniwa	True,	tu-arn

Verbs.

Die,	gido	Conceal,	gulia
Eat,	taiñ	Jump,	yūnggea
Drink,	tatthiñ	Laugh,	wia
Sleep,	wi	Scratch,	girta
Stand,	gardiñ	Forget,	wanggaramūn
Sit,	nyiwiñ	Send,	wula
Talk or speak,	lawiñ	Suck, as a child,	dhadhun
Tell,	gabbamum	Suck a wound,	baba
Walk,	yawiñ	Scold,	mo-i-a
Run	wā-ih	Swim,	yunggia
Bring,	wambawe	Fly as a bird,	minda
Take,	māna	Search or seek,	wibbun
Break,	wirgunga	Spit,	thukipa
Beat or strike,	wina	Smell,	ngadhiñ
Arise,	kangia	Throw,	yanda
Fall down,	lumawa	Whistle,	wŭngoa
Shine or glitter,	mirnanmun	Pretend,	kalea
Hear,	wanga	Vomit,	kramboiñ
Give,	wua	Dance,	wirrawa
Sing,	nēwia	Bite,	nguttha
Weep,	lūngga	Touch,	tinba
Steal,	gulima	Call,	kurnda
Ask or beg,	waia	Come,	wattai
Blow with breath,	buinba	Carry,	ginnipa
Climb,	gŭngea		

NOTES ON TIDE-GAUGES WITH A DESCRIPTION OF A NEW ONE.

By G. H. HALLIGAN, L.S., F.G.S.

[With Plates I. - III.]

[*Read before the Royal Society of N. S. Wales, June 3, 1903.*]

THE great importance of an accurate knowledge of the movements of the tides must be patent to all of us, not only from a scientific point of view, but from its direct bearing on all commercial matters in which the shipping interest is involved. In this country, where most of our river entrances have sand bars which can only be crossed at certain stages of the tide, a consideration of these matters is forced upon us, as most of our harbour works are carried out with the object of increasing the tidal scour and making the tidal range greater at our river entrances. As these circumstances occur at many other places in the world, it is not surprising that a large amount of attention of inventors and mechanics has been given to the question of recording the ebb and flow in the best and most economical manner. The machines which are here illustrated, (*Plate 1*) are intended to show the types generally used in various parts of the world. It will be seen that they differ in the arrangements of the parts; in some the cylinder, on which the record is made, is horizontal; in some vertical and in others inclined. The majority of gauges have the clock outside the cylinder it is designed to drive, though why this is done the author fails to see, while some have the clocks underneath the machine, and others on top.

But although dissimilar in details, they are all, with the exception of one, which will be referred to later on, con-

structed on the same principles, so far as the connection between the water surface and the recording pencil is concerned. Mechanical art has now reached such perfection, that little or nothing can be done to improve the working parts of many of the gauges now in use, but the connection between the water surface and the registering gear has always been recognised as the great element of error in all tide-gauges.

In Sydney Harbour, where we have a difference between highest high and lowest low water of about seven feet, we must allow for a range of nine feet in order to record possible earthquake waves or abnormal tides, the floor, on which the gauge table stands, must be, say, three feet above highest tides, and if the instrument is three feet above the floor it will be 15 feet above the level of lowest water. In all gauges (except the Richard gauge, referred to later on) this distance is bridged by a flexible band or chain, and it is just here that most of the errors creep in. At low water about 15 feet of chain is stretched between the float and the band wheel, with a very short length on the balance weight; but at high water the float is within six feet of the wheel, and 10 or 12 feet of the chain or band is then on the side of the balance weight. This means that the lower six or eight feet of the flexible band or chain is always in tension and the remainder is unequally strained in proportion to its distance from the band wheel at low water.

The continual change in the disposition of the balance weight, means a constantly increasing weight of band or chain during flood tide, and its gradual diminution during the ebb, has been partly overcome by the use of platinum wire of small sectional area in proportion to its length, but in most gauges the old fashioned brass chain or copper band is still in use.

As all material will, in time, respond to tension, it follows that the distance between the indicator on the gauge and the float is constantly increasing, and as the accuracy of the gauge depends on the constancy of this distance, it will be at once seen how serious the matter becomes. Any change that does take place is so gradual that it is not noticeable until some serious difference between the sight gauge and the recorded height has accrued, and as the error varies in every foot of the tide, and as we cannot say when the change in length commenced, it is impossible to accurately correct the readings.

For the general purposes for which tide gauges are used, such as for reducing soundings, and for current observations in hydrographic work, a difference of an inch or two does not matter, but where the gauge readings are to be ultimately used to compare the relative levels of the land and the mean sea level, it will be conceded that the utmost accuracy is desirable.

Another source of trouble with tide-gauges is the float. This should of course be made of glass, in which case it is frail and liable to injury, which means stoppage of the gauge at any time. It is generally made of copper, and becomes pitted with holes either from chemical or electrical action, and water gradually leaks in and so changes the zero of the gauge. This is another insidious enemy, as we do not know of its existence until the harm is done, and, as in the case of the gradual lengthening of the chain, we cannot correct the record when the error is discovered. In one case which came under the author's notice, the stretching of the chain was just counterbalanced by the sinking of the float for many months, but it is not often that errors are compensated in this manner.

In all gauges it is necessary to register the rise and fall on a paper of suitable size for convenient handling, and

this means the introduction of gearing for the reduction of the movement of the float. This gearing means friction, and the introduction of another element of error into the machine. On the coasts of Australasia the spring tides have a range of from five to about twelve feet, so that a reduction of about one-sixth meets all requirements, and if the clock-driven cylinder is made 24 inches in circumference, or one inch to one hour, a sheet of convenient size is obtained.

The well known scientific instrument makers MM. Richard Frères of Paris, have designed a most useful gauge by means of which almost all these sources of error have been avoided, and the machine is especially of use to surveyors, or for purposes for which temporary gauges only are required. It consists of a metal case *A* (*Plate 2*), in which is a rubber bag to which the water has access through holes in the case. A flexible brass or copper tube *B*, about ·08 inch internal diameter, is connected with the rubber bag by means of a valve on the top of the case. The other end of the tube ends in a flexible box *C*, on the top of which is a rod, connected with the arm *E*. This arm is pivoted at *D* and has, on one end a balance weight *G*, and on the other a pen or pencil *H*. The cylinder *J* is revolved by clockwork once in 24 hours.

The rubber bag in the metal case has air pumped into it at such a pressure that the pencil *H* will rest at zero when the metal case is on its bed, a few feet below the lowest known tide. As the tide rises or falls it presses unequally on the rubber bag, and this pressure is communicated through the copper tube *B* to the arm *E* and thence to the pencil *H* which traces a curve on the revolving cylinder *J*, the abscissæ representing the heights and the ordinates the hours. It is a pity that in a machine so ingeniously designed and so simple in its working and so portable, it

should be necessary to use a material so perishable as rubber, for when the bag is replaced with a new one, some difficulty occurs in bringing the pencil to the correct zero, and this of course is an essential to the adoption of the machine. Then it is obvious that, unless the air is pumped into the bag at a temperature equal to the sea water, and that this temperature remains practically the same during the time the machine is in operation, condensation will take place in the small copper tube, and the moisture, accumulating in the bends of the tube, will interfere with, if not wholly stop, the free transference of air pressure, and thus stop the working of the machine. Then again it is doubtful if any material, which could be used in the construction of the air drum C, has yet been discovered that would respond perfectly to alternate expansion and contraction for an indefinite period. These objections go to show that for permanent installations the Richard tide-gauge is not as suitable as some others, notably the Kelvin machine, (*Plate 1*), but for use on hydrographic surveys, where a gauge is seldom kept more than a few months in one place, it is invaluable. Extreme accuracy in these case is not required, so that the differences due to changes of temperature may be neglected, while any accumulation of moisture in the tube would be quickly noticed as the gauge is referred to nearly every day.

Some years ago the author designed a method of doing without the flexible band, and connecting the float and the indicator by means of lazy-tongs (*Plate 2*). This idea was first suggested by Mr. E. Bale of the Public Works Department. Great care must be exercised in making the 19 joints of the lazy-tongs, as the pencil must respond at once to the least movement of the float, and this will not take place if there is any appreciable elasticity in the rods or any lateral play in the pivots. The arrange-

ment also involves the use of a larger float in order to carry the weight of the tongs. In practice it has been found that $\frac{5}{8}$ inch hollow steel bars with gun-metal pivots $\frac{1}{4}$ inch in diameter meet all requirements, and as the weight of the tongs is only $11\frac{1}{2}$ lbs, it is not a serious matter. For permanent installations this machine does very well, as it is cheap, compact, and is not easily put out of order, but for survey work it is not sufficiently portable. It also requires a house for its protection from the weather, and a well in which the float may work, and in these respects it is similar to the other gauges herein described.

The author has long thought that if the weight of the water above the zero of the gauge could be periodically recorded, a more compact machine might be constructed than any of those now in use. He wishes to record his indebtedness to Mr. P. W. Napier of the Harbours and Rivers Office of this State, for the idea on which the gauge now illustrated was designed. (*Plate 3.*)

It consists of a chamber *A*, about half filled with mercury *B*, to which the sea water has access through the orifice *E*, filling the upper part of the chamber *C*. A tube *D* open at each end is let into this chamber *A*, and the mercury has access to this tube at the lower end. As the tide rises or falls it produces an unequal pressure on the mercury, which rises and falls correspondingly in the tube *D*. A float *G* on the mercury, conveys this motion, by means of the bent rod *H*, to a pen *J*, by means of which a curve is traced on the clock driven cylinder *F*. The whole instrument is inserted in a water-tight case (*Plate 3*) through the side of which the tube *E* extends. A level platform about two feet square and about three feet below the level of the lowest tide is prepared for each gauge, and care must be taken that the machine is lowered on to the clean surface of this platform when it is in use. The clock need only be

wound once a week, and the sheet changed at the same time, but in case a reading is required in the interval, a glass window is provided in the case, through which a great part of the cylinder *F* may be inspected without taking off the top of the case. However the whole operation of raising the gauge, opening the case, removing the used-up sheet and gumming on a new one, reclosing the case and lowering into place, does not usually take more than 15 minutes, and could be done in less time.

In the machine now in use the chamber *A* and the tube *D* are made of vulcanite, which can be easily drilled to receive the fastenings for the cylinder support and the guide for the rod *H*, but the expense of making the chamber of this material is a serious drawback. The cost in Sydney was two pounds ten shillings, and the cost of a similar chamber in earthenware, glazed on the inside, is fifteen shillings. A gauge is now being made having an earthenware mercury-chamber, for the purpose of comparing the cost of the two materials. The float *G*, the rod *H* and the cylinder *F* are of aluminium, and the remaining fittings are of brass, with the exception of the steel pinion upon which the cylinder revolves.

It is thought that the machine cannot be made more simply than the design shows, as all superfluous parts are omitted, with the result that the gauge cannot be put out of gear except by careless handling. The design of the pen *J* is such as to cause a minimum of friction on the cylinder *F*, the small knob on the back being added to or reduced in size till the ink just flows freely from the pen.

The copper tube is introduced to provide a connection between the air in the water-tight case and the outer atmosphere, in order that condensation may not take place when the case is closed on a warm day and then lowered into the cold water. The leaden weights are provided in

order that stability may be given to the apparatus in a strong current, or where it is likely to be exposed to waves or other disturbing causes. The total cost of the machine now exhibited was twelve pounds, but if made in numbers this might, the author thinks, be reduced to ten pounds.

THE SAND-DRIFT PROBLEM IN NEW SOUTH WALES.

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[*Read before the Royal Society of N. S. Wales, July 1, 1903.*]

SYNOPSIS:

THE sand-drift question is of national importance to New South Wales, and may be conveniently divided into the Coastal and Western problems. Each may be treated separately, and most people will agree that the latter is at once the more difficult and of greater urgency at the present moment. At the same time the coastal problem is increasing in importance and should be dealt with, otherwise it will become a serious drain on the public treasury and on the purses of our citizens. Stringent regulations should be issued by the Government forbidding the burning off or cutting down of the natural sand-binders (trees and shrubs) along our coast, except under suitable regulations.

I. THE COASTAL PROBLEM.

It would be difficult, and perhaps impossible, to ascertain the money loss which has accrued to the Government, to municipalities, and to private citizens in the suburbs of the cities of Sydney and Newcastle alone, in combating the sand-drift nuisance. Many private landowners, trustees of parks and cemeteries along other parts of the coast have sand encroachments which they are interested in fixing. I have for a number of years taken an interest in this question, and again draw public attention to it, because I think the nuisance can, for all practical purposes, be abated in the vicinity of large towns, provided a little expenditure be incurred and work accomplished be not allowed to be undone through neglect. As instances of what has been done locally in fighting the sand-drifts, I give notes in regard to two well known cases.

1. *Newcastle*—On the 14th October, 1886, was assented to—"An Act to authorise the resumption of certain portions of land situate in the parish of Newcastle and county of Northumberland, for the purpose of enabling the Government to arrest as far as possible the further deposit of sand thereon, and to reclaim for public purposes and dispose of the said lands as hereinafter provided."

During the year 1887, Mr. H. Czerwonka an engineer of the Public Works Department, set to work to carry out the process of reclamation, his operations consisting of cutting down, trimming and sloping banks along the sea shore; removal of existing old fences; shifting of sand; erection of brush fences and of new boundary fences; planting with grass. From first to last a considerable sum has been spent on this work; numerous trees and shrubs, chiefly from the State Forest Nursery at Gosford, have been planted in the reclamation, while a resident gardener care-taker has always been maintained since the planting staff has been withdrawn.

2. *Bondi.*—Mr. G. R. Cowdery's work in dealing with the sand nuisance in the vicinity of the tram terminus is referred to below. I would also draw attention to Mr. W. A. Smith's paper on the "Treatment of Drift-sand, as applied to the Bondi sand-dunes," (read before the Sydney University Engineering Society, October 27th 1902). This recounts the valuable work which has been begun by cutting off the supply of sand from the ocean by Mr. Smith, the District Engineer.

3. *The sand-drift problem, a forestry rather than an engineering question.*—In New South Wales works for the treatment of sand-drifts are carried out by engineers. In all other countries with which I am acquainted, they are looked upon as the legitimate work of the forester, and hence the planting work is given a prominence that it has never received with us so far. In France the work was expressly transferred from the Director General of "Ponts et Chaussées" in 1862, to the Forestry Department; in the United States the work is in the hands of the Department of Agriculture. Although the coastal sand-dune works in France are best known, those in England, Holland, Germany, the United States and Canada are very important.

4. *The three stages in the reclamation of a sand-dune.* —Sand-dune reclamation consists of three stages :—

a. Cutting off the further supply of sand from the ocean.

b. Fixing the sand by means of vegetation.

c. Maintenance of such vegetation.

The sand is of course primarily brought from the sea by the action of winds and waves. The deposit on the beach is dried and is then blown by the prevailing winds, forming dunes. Our most violent gales, in the Sydney district, come from the south-east. Let us consider the above three points in detail :

a. *Cutting off the further supply of sand from the ocean.* —To do this, what is called the "dune littorale" is formed. The old official system of constructing the protecting dune may briefly be described as follows :—

At a distance of from 150 to 200 yards from high water mark a wattle fence,[1] some 40 inches in height is erected, parallel to the general coast line, and at right angles to the direction of the prevailing wind. The drifting sand is arrested by this fence, and mounting up to windward forms a gradual slope towards the sea. After some little time this fence is overtopped, and a second is put up some 6½. feet from the base of the steep leeward slope formed partly by the sand which has been forced through the interstices of the first fence, and partly by the sand which has blown over the top, and parallel to the first fence. The space between these two fences is soon filled up, and the embryo dune assumes a certain profile. Midway between the two fences a palisade is erected. This palisade is formed of pine planks sharpened at one end, 5 feet long, 7 inches to 8 inches wide, and 1¼ inches thick. The planks are driven into the ground some 20 inches, and ¾ of an inch apart, their breadth being at right angles to the direction of the wind. As the sand drifts up the windward or west slope of the dune, it is again arrested by the palisade,

[1] Tea-tree (*Leptospermum*, etc.) would be used in coastal N. S. Wales.

though part of it filters through the interstices between the planks, and forms a steep slope to the leeward, which serves as a support to the planks. The sand now gradually mounts up, and when nearly flush with the top of the palisade, the latter is levered up some 24 inches. This process is continued until the dune is some 25 to 30 feet high, when a cordon of faggots is planted on the summit of the dune just to windward of the palisade. The palisade is now left in this last position until a third fence, which has been erected some 5 or 6 feet to the east of the leeward slope, is overtopped, and the base of the dune is increased without affecting the height by the sand blowing over the tops of the palisade and cordon. When this fence is covered, the palisade is moved back a few feet, and the sand coming over the tops of the cordon faggots fills in the space between them and the palisade. The latter is then again levered up, and the process continued until the dune assumes the final profile required. The formation of the artificial dune usually requires a period of from 15 to 18 years. The growth is naturally irregular, being dependent on the season. Steady strong winds are the most favourable. On the completion of the dune the surface is consolidated by half burying, in a vertical position, faggots composed usually of pine branches. These faggots have usually a circumference of some 14 to 16 inches and a length of 30 inches, and are planted some 14 to 16 inches apart. Between these faggots is sown the seed of the "Gourbet" or "Marram Grass" (*Ammophila arundinacea*, Host.) in quantity about 13 lbs. to the acre. The consolidation is naturally only requisite on the summit and windward slope.[1]

Schlich[2] describes a somewhat simpler method of constructing the dune littorale :—

"Although air currents are capable of moving the sand along level and gently sloping ground, they cannot lift it above a certain height. Hence it is necessary at a moderate distance (100 – 300

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[1] McNaughton, C. B., "The sand-dunes of Gascony,"—*Agricultural Journal* (Capetown), 7th February, 1895. A valuable and exhaustive paper.

[2] *Manual of Forestry*, Vol. II., p. 34; see also IV., 524.

feet) from high water level to form an artificial hill, which is high enough to arrest the forward movement of the sand, and this is done by the construction of an artificial dune, generally called the "littoral dune." With this object in view a continuous line of paling is erected, consisting of planks about 6 feet long by 6 inches wide, 1 inch thick and pointed at the lower end. The planks are inserted into the ground to about half their length, an inch apart, the direction of the line being parallel to the coast. Against this fence the sand is deposited, a certain portion being forced through the interstices and coming to rest in the comparatively quiet air immediately behind the paling. As soon as the accumulation of sand approaches the upper ends of the planks, they are pulled up about 3 feet by means of levers, and this process is repeated until the artificial dune has reached such a height that no sand can be carried over the top. Simultaneously with the first erection of the paling, a wattle fence is placed at a convenient distance behind it, to prevent the sand which has passed through the paling from being carried inland; when the first wattle fence has been entirely covered, a fresh one is made to replace it. In this way the dune is forced to adopt a moderate slope on both sides, which is essential to its permanent maintenance."

Although even this modified method has been to some extent superseded by that of M. Grandjean, to be referred to presently, I think it should be followed to some extent in special cases, *e.g.*, at Bondi and Newcastle.

In M. Grandjean's method only Marram grass is used as a rule, but fascine work is employed in cases where neglect or accident renders this necessary. The Marram grass is elastic and is used as a substitute for the more elaborate system of fascines, palings, etc., already described. The grass is freely planted in rows and the direction and closeness of the rows are modified according to circumstances. This method cannot readily be described in detail and must be undertaken by the expert forester or gardener, who will regulate his plantings according to the encroachments of

the sand. As the sand rises, the Marram, even if temporarily submerged, will push its way up and continue to grow. Finally, by judicious planting of the Marram, and encouragement of it, it is possible to obtain the "constant" for a particular spot, indicative of the height beyond which sand from the sea shore or other source is incapable of passing. When this is obtained, the "dune littorale" can be formed, and its fixation and maintenance arranged.

The dune littorale must have a surface as regular as possible, otherwise the wind speedily accentuates the unevennesses and creates ridges and depressions in the mobile sand which steadily increase in size. The profile of the dune littorale must be decided upon according to local experience. In regard to this, as indeed in regard to other points in connection with sand-dunes the personal experience and responsibility of the forester must be exercised.

b. *Fixing the sand by means of vegetation.*—In France the fixation of the sand by mechanical means and the permanent fixation by means of a permanent crop of trees proceed simultaneously; it is obvious that the one may precede the other. In France not only is fixation of the shifting sands readily accomplished as part of the ordinary business of the forester, but a timber crop is raised upon these hitherto waste lands. The chief timber tree is the Maritime or Cluster Pine (*Pinus pinaster*, Sol.; *P. maritima*, Poir). The trees are not only tapped for the turpentine they contain, a flourishing industry being the result, but the timber has considerable local value, and is even exported to England, chiefly for mining purposes.

"As regards the species there was little doubt. 'Cluster Pine,' the 'Pin Maritime,' was already flourishing in places in the Landes." What a lesson we have here! The sagacious Frenchman uses his native and well acclimatised

vegetation; the Australian seems to prefer to plant anything rather than *his* native vegetation.

I do not of course object to the acclimatisation of useful plants, and the Maritime Pine has proved useful here, but I would place native plants first for this particular service. In lieu of the Maritime Pine, I recommend the Norfolk Island Pine (*Araucaria excelsa*), as the main timber tree for the New South Wales coast for the following reasons. It revels in the sea air. Its narrow leaves and conical shape present comparatively little resistance to strong winds. It is ornamental in appearance and it furnishes a useful soft-wood. For a list of other plants recommended see p. 94.

Hitherto plantings of trees, etc., in sand reclamation works in this State have always been made from plants and not from seed; I desire to emphasise the desirability of sowing seed. If, however, seeding cannot take place, I would advocate the establishment of a small nursery within the sand-drift area. It need not be expensive, but the enormous advantage would accrue of plants being raised from the beginning in situations as nearly as possible similar to those they would ultimately occupy, while, as arrangements would not have to be made for their conveyance from distant parts, they could be planted out at the most favourable opportunity. We will now return to the French method of establishing a vegetable growth on the dunes.

In establishing trees on the dunes it is necessary to raise quick growing shelter bushes (technically known as 'nurses') at the same time. The 'nurse' I would recommend for Norfolk Island Pines is Tea-tree scrub, and particularly *Leptospermum lævigatum*. The dune is divided into strips 50 or 60 feet wide, and protected by means of a fascine fence, against the prevailing wind. The strip is then planted, quincunx fashion, with Marram grass, the centres

of the plants being, say two feet apart. The seeds of the permanent trees and of the 'nurse' are then sown between the clumps of Marram grass. The sowings should be protected with branches of tea-tree or any other scrub cheaply obtainable, sea-weed, turf, etc., and the branches and other material should be pegged down, for it is of great importance that no disturbance of the surface should occur until the permanent growth or cover is established. Each season another block is similarly treated under the protection of the previous sowing, and thus an area of any required size is put under treatment. In France the plantation of sand-dunes has passed beyond the experimental stage and there is no reason why we cannot soon say the same in New South Wales.

In the Landes, at the present day, the sowings are made from east to west in the area protected by the dune. Of course the sea (Bay of Biscay) is on the west.

"Under the old system in France it was the other way, sowings were commenced immediately under the dune and proceeded westwards. This necessitated the continual shifting of the wattle fence erected to the east of the sowing to protect it from easterly winds, whereas by sowing in the contrary direction one sowing protects the next from these winds, while the dune protects the whole sufficiently from the west, and the cost of this fence is saved in all but the eastern belt of each block. As soon as the first block is completed, a second is commenced to leeward, under the united shelter of it and the dune littorale. When this second block is in due time finished, a third is begun, and so on, the work of afforesting being steadily pushed forward until the entire area is reclaimed."[1]

At Bondi and on our coast dunes generally, the sea is on the east, and the winds to protect our plantations against are strong westerlies, hence the plantings should take the

[1] C. B. Naughton, *op. cit.*

reverse direction to those of Western France. The soil of the Landes is nearly pure silica, while underneath in places is an impermeable substratum of ferruginous sandstone, locally known as "alios," usually from 9 to 15 inches thick and at a depth of 10 inches to 2 feet below the surface, We know this to our cost at the Centennial Park, Sydney, an area which gives one much experience of sand planting. Speaking generally, I do not doubt that the "soil" conditions are much the same on the coasts of France and New South Wales.

In the vicinity of cities, *e.g.*, Sydney and Newcastle, the soil may be more or less enriched, without much expense, over limited areas; this is of course a local circumstance. If opportunities be watched, soil can sometimes be obtained for little more than cartage. Even if grass alone be required, it will be found that it is advantageous to top-dress it with soil, while arrangements should be made to secure all the available manure in the vicinity, and top-dress with it. It is a matter of common observation that many people allow the manure of horses and cows to go to waste, and some of them would even cart it free for some little distance, particularly if the municipal by-law in regard to the storage of manure in confined areas were rigidly pu in operation. A small area of ground could be set apart at the sand-drift for the storage and rotting of such manure, and it could be applied to the grass and plantation when convenient.

But where soil is not available, ashes, shale and other débris may be useful (at least for forming a covering of grass). Adjoining the sand-drift at Newcastle, the Australian Agricultural Company are the owners of a considerable block of land, which is used for colliery purposes. The Company has for a considerable time been in the habit of depositing shale and worthless coal on a large area of this

land, which consisted of shifting sand. The result has been that the sand is fixed, and grasses and other vegetation have already attached themselves to the soil (so-called), completing the fixing process and forming what will be in a very short time an excellent sward.

A similar policy has been followed by Mr. G. R. Cowdery, Engineer for Tramways, in regard to the shifting sands in the vicinity of the tramway terminus at Bondi. Here the sand filled up streets and obliterated fences, becoming a nuisance and an eyesore to the travelling public. Mr. Cowdery levelled the sand and top-dressed it with a few inches of ashes from the tramway engines. A little Couch grass *(Cynodon dactylon)* was dibbled in here and there, and now we have a grassy lawn. Alongside, serving excellently for purposes of comparison, we have a neglected area, as unsightly as the tramway portion is neat. Further, the portion untreated with a layer of ashes is not only unsightly but is a nuisance to the adjoining land, as it plentifully besprinkles it with sand at every high wind. The cinders, ashes, shale, etc., should be spread on the surface to a depth, if possible, of 6 inches.

The element of time.—One of the broad dunes on the Landes may be planted according to fixed plans requiring 30 years for their completion. And as regards the exploitation of the timber upon it it may be mentioned that the rotation at the Forest of La Teste is 60 years, for example that which began in 1890, will only be complete in 1949. It is necessary to emphasise these points because we are often in a hurry in New South Wales, and some people think plantations may be formed in pure sand and produce merchantable timber in a space of time that experts know to be out of the question.

c. *Maintenance of the vegetation.*—It is a common human failing that we are often satisfied when we initiate

a work, and we forget to provide for adequate maintenance. Adequate maintenance in the matter of sand-drift prevention is the life-blood of the whole enterprise. All these sand-drift areas should be placed under the control of the Forest Department, which should have a special staff of officers to deal with reclamation matters, (including such works as the reclamation of river banks, see this Journal Vol. XXXVI., p. 107). All areas under treatment should be regularly visited and reported upon, a printed schedule of questions being answered by the inspecting officer periodically.

(1) *Protection against fire.*—This is a matter of very great importance. Our bush-fires are, in some years, very serious agents of destruction, and it is not easy to lay down useful rules to cope with them. As regards the coastal plantings on sand-dunes, the making of fires should be prohibited under heavy penalties. In many places, the plantations will be naturally protected by the heathy country which runs along the coast line.

(2) *Fencing often necessary.*—And now I make a few recommendations applicable to planted sand-drifts in the vicinity of large centres of population. At one sand-drift reclaimed by the Government, I have seen horses, cattle, and human beings breaking down the sand banks. The caretaker slopes the sand, plants grass, etc., upon it; cattle tear out the grass, bring down the sand in large masses, and consequently destroy the surface with their hoofs. Horses run along the shore for exercise, and their owners sometimes put them on the slopes, with a result most disastrous to the reclamation. People have free access to these sandy slopes facing the ocean; they break them down, and with cattle, horses, dogs, and human beings, it is a wonder to me that there is any growth on these places at all. There is but one remedy, and that is the rigorous

fencing off above high-water mark. A substantial fence should be erected, barbed wire being freely used in its construction, the wire so close that not even the smallest dog could get in. Trespass within the enclosure should be severely punished. I have emphasised the question of absolutely excluding the public, for this is the beginning of everything, and no more laxity should be shown than is in the case of up-keep of the dykes of Holland. The works at Bondi recently undertaken by the Public Works Department are not respected as they should be by a few selfish people. They break through the fences and trample within the enclosures to make short cuts and this can only be stopped by severe measures.

5. *Plants recommended for coastal sand-dunes.*—And here I would again assert an axiom in soil-reclaiming experiments. *Use the local indigenous plants to the fullest extent.* They have arrived at their present development through a long course of environment. They have the additional advantage that in many cases they are on the spot.

INDIGENOUS TREES.

Araucaria excelsa, A. Cunn. The Norfolk Island Pine.

Lagunaria Patersonii, Don. "White Oak" of Norfolk Island and northern New South Wales.

Cupania anacardioides, A. Rich.

Melaleuca leucodendron, Linn. "Broad-leaved or White Tea-tree."

Casuarina glauca, Sieb. Salt-water Swamp Oak.

Pittosporum undulatum, Vent. The common Pittosporum.

Banksia integrifolia, Linn. f. "White or Entire-leaved Honeysuckle."

Banksia serrata, Linn. f. "Red or Saw-leaved Honeysuckle.

Eucalyptus botryoides, Sm. "Bastard Mahogany" or "Bangalay."

Eucalyptus robusta, Sm. "Swamp Mahogany."

Endiandra Sieberi, Nees. A "Corkwood."

Ficus rubiginosa, Desf. Port Jackson or Illawarra Fig.

Metrosideros tomentosa, A. Cunn. The "Pohutukawa" or Christmas tree of New Zealand, a gorgeous red-flowered species.

Pittosporum crassifolium, Bks. and Sol., and other New Zealand species.

EXOTIC TREES.

Pinus pinaster, Sol. (of which *P. maritima*, Poir, is a synonym) the Maritime or Cluster Pine.

Pinus insignis. Dougl.

Ailanthus glandulosa, Desf.

Robinia pseud-acacia, Linn.

Cupressus macrocarpa, Hartw. "Monterey Cypress."

INDIGENOUS SHRUBS.

Correa alba, Andr.

Acacia longifolia, Willd. var. *Sophoræ*, "Spreading Coast Wattle."

Leptospermum lævigatum, F.v.M. "Tea-tree."

Melaleuca ericifolia, Sm. "Bottle-brush Tea-tree" and other *Melaleucas*.

Angophora cordifolia, Cav. "Dwarf Apple."

Myoporum acuminatum, R. Br.

Westringia rosmariniformis, Sm.

Monotoca elliptica, R. Br. "A pigeon-berry Ash."

Let me particularly emphasise the value of *Leptospermum lævigatum*, Nature's special sand stay for many parts of coastal New South Wales.

EXOTIC SHRUBS.

Tamarix gallica, Linn. The Tamarisk.

Lycium Afrum, Linn. African Box-thorn.

Lupinus arboreus, the common "Tree Lupin" of Californian sand-hills.

Salix acutifolia, "The sand Willow," which has done much to bind shifting sands in Russia.

INDIGENOUS GRASSES.

Spinifex hirsutus, Labill. "Spiny rolling Grass."

The coarse creeping stems attain an enormous length, I have followed them 30 or 40 feet, powerfully rooting at the joints. On the principle that "a prophet is not without honour save in his own country," the merits of this native grass are apt to be overlooked in contemplation of the imported Marram Grass, whose merits I do not for a moment deny.

Festuca littoralis, Labill.

Cynodon dactylon, Rich. "Couch Grass."

Zoysia pungens, Willd. "Coast Couch Grass."

Imperata arundinacea, Cyr. "Blady Grass."

EXOTIC GRASSES.

Psamma arenaria, R. et S. (Syn. *Ammophila arundinacea*, Host.) "Marram Grass."

Stenotaphrum americanum, Schrank. "Buffalo Grass"; the "St. Augustine's Grass of the United States."

Saccharum arundinaceum, Retz. (Syn. *S. cilare*, Anders.), the "Mung-grass" of India.

Duthie[1] speaks of the value of this grass in sandy ground near rivers:

"These hills are composed of absolutely pure blown sand, but the grass, if planted in tufts during the rainy season, strikes root and very soon effectually retards any considerable advance of sand particles. Encouragement is thus given to the growth of other plants, which are less able to endure submergence in sand, and in this way the ground becomes reclaimed."

For a further account of this grass see *Dict. Economic Prod. India*, VI., (pt. 2) p. 2.

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[1] Report on Mr. C. E. Gladstone's planting and grass-sowing operations in the Umballa district (India)—*The Agricultural Ledger*, 1896, No. 21, (Agricultural Series, No. 18).

Saccharum spontaneum, ("Kans-grass.")

"Plays an important part in the process of reclamation. Kans possesses an enormous amount of vitality in its stems, which are capable of producing plants at every nude and joint." (Duthie, *op. cit.*)

For a further account of this grass, see *Dict. Econ. Prod. India*, VI., (pt. 2) p. 11. Both of these grasses are coarse, and are only eaten by cattle when young.

SMALL PLANTS (*non grasses*).

Mesembryauthemum æquilaterale, Haw. "Pigs' Faces."

Lippia nodiflora, Linn. A plant belonging to the Verbena family which forms a mat in nearly pure sand.

This list can be indefinitely extended.

II. THE WESTERN PROBLEM.

In dealing with the coastal drifting sands, the relation of cause and effect is very obvious, in dealing with the interior sands, their dire effects are very obvious, although their causes and source are less clear. It is with the view of drawing attention to the paucity of information in regard to the causes of our Western Sand-drifts and of endeavouring to outline a method of dealing with them on scientific principles that the present paper is submitted.

1. *Report of the Western Lands Commission, etc.*—The report of the Western Lands Commission[1] is a cyclopædia of information in regard to the condition of the far western portion of this State. A note on sandstorms is given at p. 8 with references to the evidence of witnesses on the subject. Two remarkable photographs are reproduced, one showing denudation, three feet of soil having been removed by the wind from the roots of a tree, and

[1] Western Division of New South Wales, Royal Commission to enquire into the condition of the Crown Tenants, Parts I. and II., 1901. Printed by order of the Legislative Assembly.

the other showing the sand piled up against a Station homestead.

Let me invite your attention to an admirable paper by Mr. C. A. Benbow, entitled "Interior Land Changes."[1] Mr. Benbow also delivered a lecture upon "Drifting sands of the west of New South Wales" on the 30th April last. He did not publish on this occasion, but he presented many facts well worthy of attention by citizens of this State.

Drifting sands have overwhelmed many a fair city, a fact with which every student of history and geography is familiar. By attending only to present requirements people have, by means of their flocks and herds, denuded the vegetation which naturally more or less fixes the soil, and to obtain fuel and timber they have cut down the shrubs and trees, either recklessly or without replacing them by younger growth; they have not guarded against forest or prairie fires, or when these have taken place, have not taken adequate steps to repair the damage. The devastations of war have added to the general destruction. By degrees, perhaps during a period extending over centuries, the carefully adjusted "balance of nature" has been so disturbed that desert sands have encroached on agricultural lands and have overwhelmed villages and even large cities, the cumulative results of neglect being of such magnitude that the resources of the inhabitants have at length been insufficient to cope with them. All these catastrophes are gradual, and if they be studied, and the principles they can teach us be properly understood, then the first step with the view of combatting them will have been gained.

In my paper, "Forests in their relation to Rainfall,"[2] I have produced conclusive evidence to show that uncon-

[1] *Agricultural Gazette N. S. Wales*, Oct 1901.
[2] This Journal, xxxvi., 211.

trolled destruction of trees may be attended with most disastrous consequences to any country, and in a further paper "Mitigation of Floods in the Hunter River,[1] I have endeavoured also to arrive at the first principles which result in mighty consequences.

As regards the sad state of our Western lands, which has inflicted untold misery on domestic animals and on lion-hearted humanity, am I not justified when I say that enquiries into the subject are usually too much taken up with a sad catalogue of privations and catastrophes, and that too little attention is given to directing the rays of science upon the ultimate causes of the existing state of things? Are we not in the position of an anxious physician who is trying to cope with an obscure disease; he must apply his remedies more or less empirically. But now-a-days medical men are trying to get at the origin of disease, at the pathogenic organism that causes it, at the conditions which promote its growth or retard its development, and treatment and preventive steps are based upon knowledge as far removed from empiricism as possible.

As regards the bacillus of the drifting sands of the interior, Heaven preserve me from the presumption that I have discovered it, or that I am able to suggest a wholly satisfactory remedy, but if the scientific men of this State will give attention to the subject, and systematically make observations and collect data, I do not doubt that the drifting sands of New South Wales will be kept under control.

2. *Area of sand-drift country.*—The sand-drift country extends in its greatest intensity from our western boundary to the Darling. To a lesser degree it includes most of the Cretaceous and Cainozoic territory of our geological maps. Reference may be made to the botanical map of New South

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[1] This Journal, xxxvi., p. 107.

Wales published by me;[1] much of the country marked W in that map (W 2, 3, 4) is liable to sand-drifts.

3. *Classification of Western soils.*—The western country may be divided into three classes:—

a. The black earthy plains (the "black-soil plains") which crack when dry, but which do not move.

b. Soil with more or less clay in it; this may blow away but it does not drift. Much of this country is subject to inundation during high floods.

c. Drifting sands. The soil is composed of clay, vegetable matter, and sand. The lighter component parts blow away during seasons of extreme drought when the surface is denuded of vegetation. The remaining sands—mostly red in colour but sometimes white—are the drifting sands of the west.

I presume that the drift sand is the product of the denudation or of the disintegration of the Desert Sandstone, but the origin is doubtless well known to geologists, who have chemical and other data in regard to it. At all events it is not rich in the elements which go to promote plant life.

4. *Geological origin of the moving sand.*—Where does it originate? In Central Australia, extending further towards the west than towards the east of the continent. As far as our own State is concerned, the Barrier and Grey Ranges arrest the great bulk of the sand tending to come from South Australia, and the Murray River performs a similar service in regard to the desert country in Victoria. In other words, our trouble has originated within our own borders. Between the Barrier Range and the Darling River there are tracts of sand hills and undulating sandy country which have been well grassed

[1] *Proc. Linn. Soc., N.S.W.*, 1902.

(the term is comparative) and clothed with vegetation. The vegetation being eaten out, the soil would drift, particularly in seasons of drought. In other words, much of the trans-Darling country is in a state of unstable equilibrium.

The consensus of evidence shows that the sand moves more than it used to do. What prevented this? Simply the vegetation, sparse though it was, which through a long course of ages had tended to knit it together. In fact, in sandy country, all that binds it together is vegetation.

5. *Causes of drifting sands.*—To summarise in some degree, three causes have resulted in drifting sands:—

a. *Droughts.*—Some authorities even aver that sands did not, in the old days, drift except in droughts. This is not correct but they are more mobile now.

b. *Overstocking.*—It is very easy to criticise the pastoralist for overstocking, but there are so many variables to be considered in obtaining the constant as regards the carrying capacity in a particular year that most of the overstocking is unavoidable, the result of our ignorance of the sequence of the seasons. The mechanical action of a flock of sheep, irrespective of overstocking, is important. They pulverise the soil and for many years, even before the recent crisis, the position of a flock of sheep has been readily detected, in the distance, by an attendant cloud of dust.

c. *The rabbit pest.*—This is the real cause of overstocking and it is involuntary on the part of the pastoralist. This pest has become acute during the past 20 years and has accentuated any overstocking by sheep.

6. *Prevailing Winds.*—Mr. Russell tells me that the prevailing winds in the western country, capable of piling

sand, vary from north-west to south-east. According to the preponderance and strength of these winds so will the direction of the sand-ridges vary; it will of course be borne in mind that the direction of the ridges will be at right angles to the prevailing wind.

Mr. A. W. Howitt is of opinion that the strongest winds in the Lake Eyre district of South Australia are south-west.

7. *Remedial measures.*—Since our knowledge of the inland drifting sands is so sparse, with such defective knowledge, I am afraid our remedial measures must be largely tentative. Having learnt the principle of arresting the progress of a coast sand-dune from its source and coping with it, we should endeavour, as far as possible, to apply a similar principle to the inland ones also. In dealing with the latter, a large *area* of moving sand may be the *source;* hence we must modify our tactics, forming a number of more or less parallel lines of defence at a comparatively great distance apart instead of practically one line of defence as with the narrower strips of sand on our coast.

I think that *conservation of vegetation* should be our watchword, I would subordinate planting to this. An essential condition to success is to keep stock off areas which are being conserved or planted, perhaps for a considerable period. Close planting is necessary, otherwise weeds and grasses compete unduly with the young plants, which can be thinned out as necessity arises. The remarks I have made in regard to the utilization of the native vegetation, when speaking of the coast dunes, I would particularly emphasise in speaking of those of the interior. I do not propose to exclude exotic plants, but I have no hesitation in saying that the bulk of the work of sand-binding in the interior must devolve on Australian indigenous plants.

a. *Method of planting.*—To begin with, one must, in many cases, have a nearly smooth surface of sand, and this must be locally protected with a Wattle-fence,[1] constructed of bundles of any plant-rubbish that can be spared, packed on the windward side. The surface of the sand must then be protected with branches of any kind, pegged down as far as possible. Areas thus protected should each be a few hundred feet long and say fifty feet broad, the greater length being at right angles to the prevailing wind. This protected area should be sown with seeds of the indigenous vegetation, and, as in the case of the coast dunes, the fixation of one area would protect a second area which would be similarly treated, and so on. Doubtless State aid would be required for this. At all events the State would set the example in endeavouring to combat the sand-drifts in lands not leased. And, as regards the leasehold or freehold areas, no doubt the State would supply the necessary skilled supervision to all plantings.

b. *The planting of experimental areas recommended.*—In order to give my suggestions a trial, certain experimental areas could be set apart by the Western Land Board. In the meantime maps could be prepared of the western areas, carefully indicating the shifting sands; then depôts could be established in various districts, each depôt being in touch with an experimental area or group of such areas. Each depôt should be in charge of a skilled gardener, a really good man, and we have many such in this State. While he is making his plans for the levelling and sowing of the experimental areas, he would carefully collect seeds of the different kinds of vegetation found in the district, and carefully preserve it as gardeners know how. Then at any time judged to be desirable, he could make his sowings.

[1] In using this term in Australia, one must remember that the term Wattle has the accidental meaning of Acacia with us. A Wattle fence is really a fence of thin or split saplings.

He could also, if deemed desirable, establish at each nursery a small experimental nursery. Probably his trees etc., would have to be raised by the "bamboo method" as flower-pots would be out of the question, and other receptacles (tins for jam, fish, meat, etc.) would be comparatively few. And here I may make the observation that in the afforestation of the Western Country old tins would be valuable, and these articles should, as far as possible, be carefully preserved for this purpose instead of being thrown out as at present.

The gardener-in-charge of each depôt would also encourage the native grasses and other tussocky and creeping-stemmed plants to spread. He would plant cuttings of salt-bush and other plants. The work of one gardener would be compared with that of another, and they should be encouraged to emulate each other. A good gardener (and let me say that we must have trained men, and not mere labourers, however willing) would master the planting of any sand-dune. He would also be a focus of information for a district, instructing anyone who might seek knowledge. By degrees, under the lee of the sand-dunes and in other favourable places, he would gradually experiment with other plants and would do something towards forming oases in the desert. Personally I am often in a position to supply seeds for experimental purposes, and if the matter were seriously entered upon, our numerous exchanges with foreign countries would be requested to supply seeds etc., to further this national work. These depôts would be outposts to reclaim these desert areas, and are as necessary as means of communication. Droughts would recur and even the depôts would sometimes have a hard fight to exist, but unless it is thought that nothing can be done to re-establish and improve the vegetation on the shifting sands, an opinion that, if held, I do not share, let us

systematically set to work. I am perfectly certain that if anything can be done in this direction good gardeners can do it, and preliminary work can afterwards be extended to any desired extent.

There is no necessity to supply a long list of plants for experimental cultivation, either native or exotic. I will content myself with very few. If I were permitted to carry out my plans, I would attach the gardeners-in-charge of the proposed depôts to the Botanic Gardens for a brief period, in order that they might critically examine all plants likely to be useful for their purposes which are growing in the Garden, and for exchange of ideas which must be beneficial to all good men. Then I would have experimental plantations made on the coastal sand-dunes near Sydney and study the lessons thus taught.

8. *Plants recommended for Western sand-dunes.*—Just as the Maritime Pine is the principal planted tree of the French Landes and just as I recommend the Norfolk Island Pine for our coastal sand-dunes, so I recommend the Cypress Pine (*Callitris*) as the main stand by for the shifting sands of the West. It is a tree of commercial value, and parenthetically I may enjoin discretion in cutting away away existing Pine forests out west. My policy would be to raise rows, and cross rows of Cypress Pine in sandy country inside the Barrier Range; it is natural there, and Sturt[1] floundered over successive ridges of deep loose sand and became entangled in a Pine Forest near the Barrier Range.

Sugar Gum (*Eucalyptus corynocalyx*). *E. fasciculosa*, F.v.M., and other Western eucalypts, (especially Mallees) should be encouraged.

Various Acacias such as Mulga (*A. aneura*), Yarran (*A. homalophylla*), Myall (*A. pendula*), *A. cibaria*, *A. sentis*,

[1] *Narrative of an Expedition etc.*, (1849) I., 223, also II., 34.

and many others should be freely grown. The seeds of Acacias maintain their vitality for a considerable period.

Casuarina—various kinds of Belar and Bull Oak. I would also introduce the Desert Oak (*C. Decaisneana*) of Western Australia, the Needlewood (*Hakea leucoptera*) and many other trees and shrubs.

One plant of Porcupine Grass extends in an ever widening circle, the centre becoming dead and hollow. This is a most important natural sand-binder for the sand-hills and should be conserved. The native grasses in general should be encouraged, as I have already indicated.

Turning to exotic plants, some of the Cow-peas (*Vigna Catjang*) have been recommended as sand-binders. I would also try the sheeps' Burnet (*Poterium sanguisorba*) with its large root stock.

On the Mesas of Arizona and Western Texas is found the "running mesquite" (*Bouteloua oligostachya*). This would probably be worth a trial.

The Carob tree is very drought-resistant and might be further experimented with. So also the Pepper Tree (*Schinus molle*) a useful shade tree, though not of use for anything else.

Amongst economic plants the Date Palm takes high rank and it has for many years been acclimatised in the desert country north of South Australia. I have tasted very fair dates from these palms for several years.

"The results of an experimental planting made by the U. S. Division of Forestry in 1890 on the sand-hills of Nebraska seems to have proved that the Banksian Pine (*Pinus divaricata*) is one of the best adapted species for planting in arid conditions."[1]

But, as I have already observed, if we could get the depôts I have advocated established or promised, I could get many kinds of seeds for experimental purposes from the arid country in India, North Africa and the Western United States.

[1] *Forestry Quarterly*, No. 2, p. 80. See also "Notes on Sand-drift planting in Nebraska," *U. S. Year-book of Agric.* (1895).

ALUMINIUM THE CHIEF INORGANIC ELEMENT IN A PROTEACEOUS TREE, AND THE OCCURRENCE OF ALUMINIUM SUCCINATE IN TREES OF THIS SPECIES.

By HENRY G. SMITH, F.C.S.,
Assistant Curator, Technological Museum, Sydney.

[With Plate IV.]

[*Read before the Royal Society of N. S. Wales, July 1, 1903.*]

Orites excelsa, R. Br., a tree belonging to the Natural Order Proteaceæ, occurs somewhat plentifully in northern New South Wales and Queensland. It is often a tall tree with a diameter up to three feet. It has prettily figured timber, the medullary rays being very pronounced and extending from the centre of the tree to the bark. It is a useful wood for the cabinet maker. It is one of the many trees known generally in Australia as "Silky Oaks." It is a timber of comparatively low specific gravity and is usually light in colour. It may now be said that scientifically its interest lies in the fact that it utilises the element aluminium in large quantities in its construction, and so differs from all other flowering plants, so far as these have been investigated. Aluminium appears to be necessary to the growth of this tree, as in the ash from the four specimens investigated, large quantities of alumina were found. Occasionally the amount taken up is abnormal, as in the Queensland specimen, and when this occurs the excess is deposited in cavities as a basic aluminium succinate.

In November 1895 a paper was read before this Society by Mr. J. H. Maiden, F.L.S. and myself, on a natural deposit of aluminium succinate found occurring in the timber of a "Silky Oak" which at that time was thought to be *Grevillea robusta*. From the evidence here produced it is most

probable that that deposit was obtained from the timber of the "Silky Oak" *Orites excelsa*, and not from that of *Grevillea robusta*. This mistake might easily occur as the same vernacular name is applied to both trees.

My colleague Mr. R. T. Baker, F.L.S., (to whom I am much indebted for botanical information in preparing this paper) assures me that the discrimination between the timbers of these two species is not easy, the resemblance between them being often most marked, and that it is necessary to procure further botanical evidence before the identity of the timber can be placed beyond dispute. The results of the present investigation may, perhaps, supply a simple method of diagnosis, if at any time such is needed. It can readily be understood how easily these timbers might be mistaken for each other at the saw mills, and thus supplied indiscriminately.

The occurrence of the deposit of aluminium succinate was, at the time of its first discovery, thought to be of some physiological importance, and efforts were made to procure, if possible, the sap from the living trees of *G. robusta*, so that the constituents might be determined. A small quantity of this sap was procured for me later by Mr. W. P. Pope, the Forester in the Lismore District; from this I made as complete an analysis as possible, the results of which were submitted to this Society in a paper read, October 1896. The presence of free butyric acid was determined in the sap, so that the origin of the succinic acid was thought to be explained, it being derived from the butyric acid of the sap by natural oxidation. The origin of the aluminium was not so evident, because the investigation showed that element to be absent in the sap, and the ash of a sample of the wood obtained from an undoubted tree of *G. robusta* was quite free from alumina. There the matter remained until quite recently, when the

Museum came into possession of fresh material, and the investigation of this timber and its deposit of aluminium succinate shows clearly that the failure to indicate the origin of the aluminium in the previous case, was due to the fact that *Grevillea robusta* is not the tree in which this aluminium succinate occurs. I have made investigation of the ash of the following trees belonging to this genus:

1. *Grevillea robusta*, Museum specimen from Lismore.
2. *G. robusta*, cultivated tree growing at Marrickville.
3. *G. Hilliana*, Museum specimen from Bangalow.
4. *G. Hilliana*, cultivated tree growing at Ashfield.
5. *G. striata*, Museum specimen from Girilambone.

The ash of all these trees were found to be normal, consisting largely of the carbonates of lime and magnesia, together with the other usual ash constituents, but no alumina was present in either sample. It is thus evident that aluminium is not used by these species of *Grevillea*, and it is, therefore, hardly possible for an aluminium succinate to occur in either of them.

It is generally accepted that the element aluminium is hardly ever utilised by flowering plants in their construction, as only in very few instances has it been detected in them. Some authors are most emphatic as regards the absence of aluminium in flowering plants.

Church[1] shows the presence of aluminium in certain Cryptogams, and he obtained as much as 33·5% of alumina in the ash of *Lycopodium alpinum*, and 15·24% in that of *L. clavatum*.

Allen[2] is most pronounced regarding the absence of aluminium in flowering plants, even going so far as to suggest the presence of clay as the origin of the small amount of alumina occasionally found in their ash.

[1] Chem. News, xxx., 137.
[2] Commercial Organic Analysis, Vol. I., p. 38.

Watts[1] after recording the presence of aluminium in the Lycopods, says, "In most other plants alumina is altogether absent, any small quantities that may be found in the ash, generally arising from impurity of the reagents."

Mr. W. A. Dixon, F.I.C., etc., in two papers[2] to this Society shows the presence of aluminium in the ash of some epiphytic ferns, and in the ash of some epiphytic orchids, but he found that there was a complete absence of that element in the ash of the wood and bark of the tree on which the specimen of the Stag's Horn Fern, *Platycerium grande* was growing. In the latter paper Mr. Dixon says, "I would not, however, venture to say definitely that alumina is a necessary ash constituent without a further careful examination of other specimens of the plant." The reason given being a more or less external contamination.

In Roscoe and Schorlemmer[3] appears the following:—"Athough alumina is largely contained in all fertile soil, it is not taken up by plants with the exception of a few cryptogams, especially the species of Lycopodiums. The ash of *L. clavatum* contains up to 26·65%, and that of *L. chamæcyparissus* even as much as 57·26% of alumina, whilst other plants, such as oak, fig and birch grown on the same soil contain none. (Aderholdt, Ann. Chem. Pharm. lxxxii., III.)"

The general statement that alumina is never found amongst the constituents of flowering plants is perhaps too sweeping.

L'Hote[4] shows that aluminium occurs in wine and in grapes.

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[1] Dictionary of Chemistry, Vol. I., p. 417.

[2] Journ. Roy. Soc. N. S. Wales, xv., 1881, p. 175, and xvi., 1882, p. 175.

[3] Treatise on Chemistry, Vol. II., part i., p. 437.

[4] Compt. Rend. 104, p. 853.

Bergstrand[1] points out that the ash of *Rubus arcticus* found growing on the alum charged soil near Westerbotten, contains as much as 5·6% of alumina.

J. Ricciardi[2] makes the statement that alumina is found in the ash of all Italian plants; he gives analyses of the ash of vines grown on various soils, in which he found alumina up to 1·14%. He also gives a list of several other plants in the ash of which alumina was present, although 0·002% seems almost a negligible quantity.

Yoshida[3] carried out a series of researches to decide the presence or absence of aluminium in plants growing on the soil of the Plain of Musashi in which Tokyo is situated, and which soil is of volcanic origin and remarkable for the large proportion of alumina soluble in hydrochloric acid which it contains. He thought that if aluminium did occur in flowering plants, then certainly this would be the best locality to choose for the purpose. He records the results of eleven determinations of the ash of various plants, in all of which, except one, he detected alumina, ranging in amount from 0·272% to 0·053%. This chemist had previously found alumina in small amount in the aqueous portion of the latex of the Lacquer tree of Japan, *Rhus vernicifera.*

Berthelot and André[4] state that the roots of lucerne contain 0·45% to 0·5% of alumina in the ash, and the ash of the roots of couch grass 0·12%, but that the leaves of Lupin contained only 0·037%.

Professor Church[5] at a meeting of the Scientific Committee of the Royal Horticultural Society, called attention to the, apparently, general presence of aluminium in flowering plants, and said that he had detected it in Cherry-tree

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[1] Deut. Chem. Ges. Ber., IX., p. 857.
[2] Gaz. Chem. Ital., 19, p. 150.
[3] Journ. Chem. Soc., 51, 1887, p. 748.
[4] Compt. Rend. 1895, 120, 288–290.
[5] Pharm. Journ., 1887-8, p. 625.

gum, gum arabic, tragacanth, etc.; he assumed that it is probably absorbed accidentally by the roots and that it plays no part in vegetable physiology.

A. H. Allen[1] points out that aluminium, in minute proportions, is a normal constituent of wheat.

But what do physiologists say about it?

Dr. W. Pfeffer[2] says that aluminium though universally distributed is present only in small amount in most plants, except the Lycopods.

Dr. Sorauer[3] writes:—"In spite of the wide distribution of clay in soil and in rocks, its chief constituent, aluminium, is confined in its occurrence to very few plants (lichens and club mosses)."

In the Natural History of Plants[4] the following appears: "It is worthy of note that alumina which is so widely distributed and easily accessible to plants is only very rarely absorbed. The ash of *Lycopodium* is the only kind in which this substance has been identified with certainty in any considerable quantities."

Sachs[5] in describing the constituents invariably found in the ashes of plants, states that the following occur in very rare cases and under special circumstances:—aluminium, copper, zinc, cobalt, nickel, and strontium.

The above short general summary regarding the presence of aluminium in flowering plants, indicates that occasionally this element is present, although in very small amount, and in no instance does it appear to have been found in quantity in any of the Phanerogams.

It is the purpose of this paper as already hinted, to bring under the notice of this Society a flowering plant of luxur-

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[1] Analyist, 13, 41 – 43.
[2] Physiology of Plants, (A. J. Ewart's translation) p. 437.
[3] A Treatise on the Physiology of Plants, p. 36.
[4] Kerner and Oliver, p. 68. [5] Text-book of Botany, p. 695.

ious growth, the principal inorganic element of which is aluminium. This element occurs in this tree (*Orites excelsa*) as, apparently, a necessary inorganic constituent to its growth, and it also occurs as deposits of a basic aluminium succinate, the latter being found filling the cavities and natural fissures of the wood. The deposition of aluminium succinate in living trees, in quantity, is exceedingly interesting, because the salt is composed of an acid rarely occurring in quantity in plant life, and in combination with a base which as shown above is scarcely ever present. The deposit, however, is of even less physiological interest than the tree itself from which it is obtained. The rarity of occurrence of even traces of aluminium in the Phanerogams makes this discovery of more than passing interest. It does not follow, perhaps, that the detection of this or any other element in the ash of plants is *a priori* evidence of the necessity of this element in the building up of any particular plant, this evidence being usually obtained by direct experiment; but from our present knowledge it can hardly be denied that aluminium is necessary to the construction of *Orites excelsa*, because of the enormous amount of that element often found in the ash, and the formation of the aluminium succinate is probably Nature's method for getting rid of an excess.

In the Queensland sample the vascular portion can occasionally be stripped from the medullary rays in layers, forming a cellular open network of fibre, and this when carefully ignited leaves a skeleton of ash resembling in shape the portion taken, and consisting almost entirely of alumina. So pronounced is it that if the skeleton of ash be moistened with a solution of cobalt nitrate and ignited before the blowpipe, the characteristic blue colour is readily obtained, the other salts being too small in amount to interfere with the reaction. The ash of this specimen was also infusible or fusible with great difficulty.

The conditions under which the aluminium has been assimilated by this species must be either favourable or unfavourable, but it can hardly be the latter when the trees from the various localities are considered. A photograph of the log of the Queensland specimen, as received at the Museum, is here reproduced, and it will be seen that the section of the tree is about three feet in diameter. This timber, as "Silky Oak" was procured from Queensland by the Colonial Sugar Company for the manfacture of casks. It is to the kindness of Mr. T. Steel, F.C.S., to Mr. T. U. Walton, B.Sc., and to the General Manager of the Company, that the Museum has come into possession of this material.

From the photograph it will be seen that the cavity in the tree (which is not due to decay but to abnormal growth) was completely filled with the aluminium succinate, but it had been removed from the larger end before the photograph was taken. A considerable quantity of the succinate was obtained from the cavity, so that it has been possible to elucidate most of the problems suggested by the occurrence of this deposit. (For photograph see *Plate 4*.)

It seems reasonable to expect that aluminium, probably as a butyrate, or as an aluminate of potash, will be found in the sap of *Orites excelsa*, because free butyric acid was the only volatile acid found in the deposit, and alumina as potassium aluminate was present in the soluble portion of the ash when this was boiled with water. When the log was cut it was still unseasoned, and as it dried, microscopic masses (probably the aluminium succinate) accumulated at the ends of some of the cells, indicating that the salts were originally in solution in the sap.

Butyric acid appears to be a constant constituent in the sap of this class of Proteaceous trees, and I had previously found it in the sap of *Grevillea robusta*. The question

naturally arises, therefore, as to why aluminium is used by *Orites excelsa* and not by *Grevillea robusta*, or other allied plants. It might be expected that the solvent action of the butyric acid in the sap would be equal in both cases. Is it that the iso-form is present in the sap of *G. robusta?* The formation of succinic acid determines the form in *Orites excelsa*, as it must be the normal acid $CH_3 \cdot CH_2 \cdot CH_2 \cdot COOH$.

When the analysis of the ash of the Queensland sample had been completed, it became necessary to confirm the extraordinary results by the investigation of other samples. In the Museum collections there were three specimens of the timber of *Orites excelsa*, obtained from various localities in New South Wales. Two of these timber specimens had been forwarded by the Museum collector (Mr. W. Baüerlen) from Bangalow and from Mullimbimby in the northern part of the State; the other specimen had been collected by Mr. J. H. Maiden, F.L.S., at the Dorrigo Forest Reserve, also in northern New South Wales.

In the ash of all these samples, alumina was present in large quantities. It is also worthy of note that in the ash of the sample from Mullimbimby, cobalt was found, and when separated from the manganese present, a splendid cobalt-blue borax bead was obtained. From the analyses it appears that the alumina in the ash of normal specimens of this tree ranges between 35% and 45%; the tendency, however, seems to be for the tree to absorb much more than that amount of alumina, even up to 80%. When this excessive amount of alumina is present, the conditions are evidently favourable for the formation of the aluminium succinate.

The Aluminium Succinate.

This deposit is in places quite white; occasionally it is quite soft, and is easily powdered. It seems to be a salt

of somewhat constant composition, as the analyses of this and the previous sample agree very closely. The water present does not appear to be necessary to its chemical formula, because after removal from the log the powdered material steadily lost weight in the air, and practically the whole of the water was driven off at a temperature not exceeding 54° C. :—

Heated in air oven for 2 hours at 50 – 54° C., loss = 29·8%
" " " 1 hour at 100 – 110° C., " = 0·24%
" " " 1 hour at 160—180° C., " none
∴ loss of water = 30·04%[1]

The dried material was then ignited before the blowpipe until constant in weight when 41·36% had been burnt away, leaving 28·6% of alumina. The residue consisted practically of alumina, the merest trace of lime being detected, and a quantitative determination gave practically 100% of alumina.

The composition of the material may be thus stated :—

Alumina	= 28·60 per cent.
Succinic acid	= 41·36 "
Water	= 30·04 "

with traces of lime and free butyric acid.

In the previous paper (this Society 1895) the formula arranged from the results was $Al_2(C_4H_4O_4)_3Al_2O_3$. This formula is again derived from this present material, as by discarding the water the following results are obtained :—

Alumina	= 40·88 per cent.
Succinic acid	= 59·12 "
	100·00

The above formula gives theoretically

$2\ Al_2O_3$	= 40·617 per cent.
$(C_{12}H_{12}O_9)$	= 59·383 "
	100·000

[1] The purest white material was taken for these determinations.

By no other arrangement has it been possible to devise a formula which agrees so closely with the analytical results. The formula for this deposit, is therefore, when pure,

$$Al_2(C_4H_4O_4)_3Al_2O_3.$$

In the less pure portion of the deposit the odour of butyric acid was somewhat strongly marked. In order to prove the presence, or otherwise, of this acid, 50 grams of the material was boiled for three hours in water, using a reflex condenser; the volatile acids were then distilled off and titrated with semi-normal soda. The amount of acid distilled equalled 0·1356% of the total succinate taken; the remainder in the flask was filtered, and the dark filtrate decolourised with animal charcoal; the filtrate on titration gave an additional 0·0574% of acid. On evaporation no succinic acid could be detected, so that the total acid extracted was 0·193% calculated as butyric.

A fresh quantity (about half a pound) of the material was then boiled and distilled as in the previous case, the distillate exactly neutralised with barium hydrate solution and the barium salt prepared in the usual way. This was ignited into barium sulphate with the following result:—0·4349 gram of the barium salt gave 0·3245 gram $BaSO_4$ = 74·62%. The theoretical amount of $BaSO_4$ obtained from barium butyrate ($Ba\,2C_4H_7O_2$) is 74·91%. Butyric acid is, therefore, the only volatile acid present in the deposit. Acetic acid is quite absent. Glycerol could not be detected so that the butyric acid is free.

The succinic acid was prepared from the deposit in the same manner as previously recorded (*loc. cit.*), where is also given the analysis of the acid together with other characteristic reactions of the deposit. That the aluminium is largely present as an aluminate before deposition as a succinate, is suggested from the analyses of the ash of the

wood, but proof of this can only be obtained from an investigation of the sap of living trees.

THE ASH OF THE TIMBERS.

The portions of wood burnt were selected so that it was impossible for the ash to be contaminated with extraneous material. In the Queensland specimen it was taken as far from the deposit of succinate as possible, without including the extreme outer portion of the log. The wood was burnt in a platinum dish at as low a temperature as possible. The ash in all cases was very bulky but very light, and consisted of the skeleton of the cellular portion of the wood. The ash of the Queensland sample was quite white, the manganese only being present in minute traces. The sample from Mullimbimby gave a light-brown ash, probably owing to the presence of the comparatively large amount of manganese present. Cobalt was also found in this ash, so that apparently deposits of cobaltiferous manganese exist in the district where this tree grew. No cobalt could be detected in the ash of either of the other samples, but manganese was a constant constituent in the ash of all of them, as well as in the ash of all the *Grevilleas* tested. Iron appears to be almost or quite absent in the ash of *Orites excelsa*, as it was only found in traces in either specimen, and the alumina after ignition was almost colourless. Even when precipitated as a basic acetate the precipitate was colourless. Probably the alumina practically takes the place of iron in this species. A large amount of potash was found, but it occurred in all cases as potassium aluminate (Al_2O_3 K_2O). The ash from the Dorrigo specimen gave nearly 35% soluble in boiling water. The aqueous solutions were always slightly alkaline and on standing some time slowly decomposed with deposition of alumina. No carbonates were detected in the soluble portion of either sample. As the chlorine increased in amount, so did the soda in the same ratio, so that the greater portion of the chlorine was

present as sodium chloride. It is remarkable how small an amount of phosphates occur in the ash of this species. The same remark applies to the sulphates, but all the sulphates were soluble, while the phosphates were insoluble in water. It is evident that alumina does not care to combine in the plant with either sulphuric or phosphoric acids. The CO_2 appears to be combined with the lime and magnesia—the amount of carbonates was very small in the ash of the Queensland sample. As the amount of soluble alumina increases, so does the potash and in the same proportion, but it only occurs in combination with the alumina. If it were not so originally, then some of the potash would undoubtedly be burnt into carbonate, but this is not the case, and the result is strong evidence that the alumina occurs in the tree in solution as potassium aluminate. The following table will illustrate this:—

Locality of Tree.	Insoluble Alumina.	Soluble Alumina.	Potash K_2O.
Queensland specimen	72·18	7·43	6·98
Mullimbimby ,,	23·71	12·33	10·91
Dorrigo ,,	26·47	16·56	14·96

The alkalis were determined in the filtrate from the alumina by preparing in the usual way and titrating the total chlorides. The phosphoric acid was separated as molybdate, and the amount found subtracted from the alumina.

As sufficient material has been obtained to allow of some for distribution, I am permitted to state that anyone interested in the physiological aspect of this question, can obtain a small specimen of the wood of the Queensland sample together with a portion of the aluminium succinate, by applying to the Curator of the Technological Museum, Sydney. I am indebted to Mr. J. W. Tremain for the photograph of the log.

The following are the tabulated results of the analyses of the various samples of wood of the trees of *Orites excelsa.*

	Queensland.	Mullimbimby	Dorrigo.	Bangalow.
Percentage of ash on anhydrous wood.	0·639	0·684	0·673	0·706
Al_2O_3	79·61	36·04	43·03	38·77
K_2O	6·98	10·91	14·96	...
Na_2O	trace	1·59	1·13	...
CaO	1·99	11·25	2·63	...
MgO	3·59	13·87	16·12	...
Mn_3O_4	trace	3·01	trace	0·48
Cl	0·25	3·03	1·54	...
P_2O_5	0·96	1·31	1·70	1·26
SO_3	0·85	0·13	0·26	...
SiO_2	3·64	0·62	0·36	...
CO_2	2·54	18·82	18·617 by difference	...
Iron	trace	trace	trace	trace
Cobalt	none	trace	none	none
	100·410	100·580	100·347	
Oxygen equal to the halogen	0·056	0·682	0·347	
Total........	100·354	99·898	100·000	

ECONOMIC EFFECT OF SANITARY WORKS.

By J. HAYDON CARDEW, Assoc. M. Inst. C.E.

[With Plates V. - IX.]

[*Read before the Royal Society of N. S. Wales, August 5, 1903.*]

THE benefits arising from judiciously considered and economically designed sanitary works are scarcely realized or appreciated by the general public, and even municipal bodies who are supposed to be the custodians of the public health are not fully seized of their great importance. The City of Sydney so far has led the way in sanitary works in Australia and may now be said to have a complete system of water supply and sewerage works, which although leaving much to be desired, especially in the department of water supply and house connections, may be considered as fairly effective, and if viewed from the standpoint of sanitary results alone should serve as an admirable object lesson to the rest of Australia.

The disclosures made in the city and suburbs of Sydney during the plague scare of 1900, the great difficulty experienced by the Local Health Authorities in getting property owners to connect their houses with the sewers, and the neglect and carelessness of house-holders in their treatment of sanitary fittings show the great ignorance that still exists amongst the people regarding sanitation, and the lack of appreciation or knowledge of the vast benefits conferred by sanitary works. The disinclination of property owners to make sewer connections is no doubt due principally to a selfish parsimony, which they are too short sighted to perceive, re-acts most prejudically against their own interests, and the negligent and careless use of sanitary appliances is due to an ignorance which is not only deplor-

able, but is fraught with the most serious consequences to the health of the household.

The author has always held that the elements of sanitary science should be taught in the Public Schools, and that every child should be trained to understand that any breach of nature's laws is a crime that will inevitably bring its own punishment, inexorably involving the innocent and the guilty; until these lessons are taught to the youth of Australia so long will the adults be ignorant of the maxim that "cleanliness is next to godliness," and, as certain as the boy is the father of the man, so certain is it that the results of early training will be apparent for good or evil in the adult population.

But the object of this paper is to crystallise the facts (so well known to all the members of this Society) of the great economic advantages arising from sanitary works, and to so illuminate them that they shall be apparent to all, and further, to supply some data to municipal and local authorities in Australia to guide them in determining what they would be justified in attempting on behalf of the sanitary welfare of the communities they represent. When the construction of sanitary works is under contemplation, the only view generally taken of the ultimate effect of such works is the increase of rates that will be necessary to pay interest and to liquidate the capital in a certain number of years, but it must be apparent that the amount of rate necessary for that purpose is not the true measure of the cost involved in securing the many benefits accruing from the adoption of sanitary services, and the author will endeavour to show that this view is an extremely narrow one, and that the increased rate is a very exaggerated measure of the cost of the benefit secured.

As regards the definition of the terms sanitary services, it is taken for the purposes of this paper to apply to the

two principal domestic requirements of water supply and sewerage, for though there are other services such as collection of garbage and the cleansing of the public streets, which improve the sanitary condition of towns, there can be no question that a copious supply of water at a high pressure, and a system of sewers that will remove all impurities from dwellings are of the greatest importance in conserving the public health, and experience teaches us that they are the primary factors in reducing the death rate; moreover, the fact has been proved by statistics in scores of places, where the effects of water supply and sewerage works on the public health have been under close scrutiny for many years. For instance, in London the average death rate of 24·8 per thousand for the decennial period ending 1850 has been reduced to 19·5 per thousand for the decennial period ending 1890, in Glasgow the death rate has been reduced from 56 in 1847 to 25 in 1893, in Sydney the average death rate of 21·02 for 15 years ending 1885 has been reduced to 15·38 for the 15 years ending 1900, and similar results can be seen from the record of other places given in the appendix (A); the periods embraced by these statistics are those during which water supply and sewerage works have been actively progressing. With regard to the relative importance of each of these two services, that of water supply has always been in the greatest demand and the most popular with the general public, the question of sewerage being deferred to a later period or until such time as the increased death rate from typhoid and other zymotic diseases has been forced upon the attention of the public, but sanitary engineers and scientists have always considered both services of equal importance to the public health; owing to the lack of data it is impossible to differentiate the benefits arising from each system, but the general experience has been that for a short time after the installation of a water supply the

death rate is reduced, but sooner or later, owing to the saturation of the soil by fouled water and the presence in the public streets and gutters of liquid filth discharged from bath rooms, lavatories, wash houses and stables, the death rate commences to increase, and it has then been known to reach a higher figure than before the advent of the water supply, a fact that has been specially noted in the suburbs around Sydney. See death rate and water supply curve for Sydney period ending 1885 and Melbourne ending 1889.

The principal object of all sanitary services should be not only the provision of comforts and conveniences to the public but the reduction of the death rate and its concomitant sickness, the accomplishment of which, in itself alone, is a very fair measure of the prosperity and well being of the people: the saving of the adult lives from premature death means a saving of money, and as many eminent medical men have proved that for every death that occurs there are from 20 to 30 cases of sickness, all involving loss of money and dislocation of business, the aggregate gain due to a reduced death rate in a large community is enormous. So that as regards benefits, the first and greatest is the reduction of the death rate, and in fact it may be said that the accomplishment of this great object is the achievement more or less directly or indirectly of all the other benefits that follow.

In order to understand fully the great blessing conferred by sanitary works in large cities it is only necessary to take a retrospective view of the state of affairs in the City of London in bygone days. History tells us that in the year 1290 the accumulation of filth in all the water courses traversing the city was appalling, and the exhalations from the Fleet Ditch, as it was called, a creek draining about 400 acres, impregnated the air of the district with

vile and noxious gases: in those days the population, which amounted to about 80,000, had to be supplemented by large importations from the country owing to the dreadful mortality caused by filth diseases: in 1307 the river Thames became so fouled and choked with all manner of filth, that, incredible as it may appear, it actually became inaccessible to ships: fœcal matter, urine, garbage, and other filthy ordure was cast indiscriminately into the street and foot passengers generally preferred the centre of the road for fear of having the contents of domestic utensils emptied on their heads from upper story windows; cesspools, which were the luxury of the rich, were emptied by pumping into the street gutters, the effluent finding its way to the lowest levels, thus breeding disease and death: is it any wonder that horrible epidemics like the spotted plague, the black death, sweating sickness, dancing, mewing and biting mania, and other horrors of filth production raged amongst the population. Prof. Corfield states that black death killed one-third of the inhabitants of the old world in one invasion.

In 1531, Henry VIII., appointed the first commission to report on sewers, it was renewed in 1548 by Edward VI., and it was extended by James I., in 1607, and subsequently other districts were granted similar commissions as the population increased and extended; there are no records of the accomplishments of the earlier commissions, but in 1637 the important work of bridging and covering in of the Fleet ditch was completed, and it is probable, from the evidence of the death rate between the years 1531 and 1637, that very little else was done up to that date to remedy the insanitary state of the city; the covering in of the Fleet ditch appears to have produced slightly beneficial results, for between the years 1600 and 1650 the death rate decreased from 233·5 per thousand to 216·8 per thou-

sand: it is probable that in 1665 the death rate increased, as the plague carried off 685,000 of the inhabitants, but thereafter, probably due to the cleansing effects of the Great Fire of London and the rebuilding of the city, the reduction of the death rate progressed very rapidly, until in 1750, it had reached what may be considered for those days the low rate of 42·5 per thousand: in 1801 it was reduced to 28·1, and in 1851 it had reached 24·2, (see diagram fig. 2), but it was not until 1841 that any decisive steps were taken to provide a system of sewers, and until 1848 the discharge of house sewage into the sewers was forbidden and people were compelled to construct cesspools.

In 1843 a Commission known as "The Health of Towns Commission," comprising many eminent men, amongst whom were two celebrated engineers, Mr. Robert Stephenson, M. Inst. C.E., and Mr. W. Cubitt, M. Inst. C.E., was appointed by Her Majesty Queen Victoria, to report on the sanitary condition of large towns in England. This commission investigated the state of the Metropolis and 50 large towns, and issued a report in 1844 describing the deplorable insanitary conditions of the inhabitants owing to the absence of sewerage for house drainage, the only drainage works in existence being principally for surface waters; in some of the largest and most populous towns all connections with the sewers by house drains or cesspools or water closets was prohibited under a penalty. In the metropolis the connection of house drains was deemed a privilege only to be obtained at considerable expense, which restricted the use of the sewers to the wealthy. Cesspools, usually of inferior construction, were provided for the reception of fœcal matters, the liquids usually escaping into the surrounding earth or escaping by means of surface water sewers: these cesspools were fearfully offensive, and were sometimes situated beneath the houses even in fashionable

quarters, and some cases occurred in which there existed *entire streets* without any privy accommodation whatever. The evidence further shewed that in some instances where there were main drains tolerably well formed, for the want of proper water supply both house drains and sewers only acted as extended cesspools.

In order to illustrate the reduction of the death rate consequent upon the construction of sanitary works, the author has plotted the curves for London, Sydney, and Melbourne (Figs. 1, 3, and 4) an inspection of which will shew how marked the decline has been since their inauguration, and on the same diagram are plotted the population curves for those cities, and the capital expended on the works, so that comparison may be made between the decline of the death rate, the increase of the population, and the capital cost of securing those wonderful results. Appendix "A" has been prepared giving the population, death rate, and expenditure on works for 13 well known cities, by means of which a more extended comparison may be made, and fig. 5 illustrates diagrammatically the same information. The illustrations here given clearly show that the reduction of the death rate is due to the construction of sanitary works, a result that cannot fail to be highly gratifying to engineers.

The number of lives saved the world over, during the last twenty years, through the agency of sanitary works, amounts to many millions, and for the 13 cities I have quoted, it amounts to over one million. The assessment in money value of these lives saved from destruction is a very difficult matter owing to the great variation in the estimated value of human life: many people will tell you that human life is above price and others say that a very large proportion of human beings are only fit for powder, but the eminent engineer Mr. Baldwin Latham, M. Inst. C.E.,

in his excellent work on sanitary engineering, made an estimate of the value accruing from sanitary services, and it may prove interesting to quote from him. He says, "An estimate of the probable effect of the sanitary works can be propounded in this way :—

First, the saving in the cost of funerals, inclusive of mourning and fees, which upon an average may be set down at £5 each.

Secondly the saving by reason of the escape from sickness, with its cost including the value of labour which is lost. To be upon the safe side, it may be taken, for every life saved by sanitary works, twenty-five persons would escape sickness and that £1 per case would represent but a moderate value of the result, including loss of time, physic, medical and other attendance.

Thirdly, the value of the labour saved to the country by the prevention of premature death—for every adult female 5s. per week, and for every adult male 10s. per week, or a mean of 7s. 6d. per week may be taken as the value of the labour over and above the cost of maintenance.

By using the above figures in connection with the lives saved, we shall get the money value of the benefit conferred by the works. Taking the town of Croydon as an example, the average mortality for eight years, 1848 to 1855 inclusive, was 24·03 per thousand, and for the twenty years since 1855 it has averaged 19·56 per thousand, shewing a saving of 4·47 per thousand per annum. The mean population for twenty years since 1855, when the sanitary works may be said to have been completed has been 43,912.

By taking the mean saving of life 4·47 per thousand and multiplying it by the mean population, and again by the number of years, we get $43·912 \times 4·47 \times 20 = 3,936$ lives saved; of this number about six-tenths would be adults or persons above the age of twenty, and probably one-tenth

of these would be infirm from age: by making this deduction we still have 2,121 persons in the full vigour of life who have been saved. Then we have—

3,926 funerals etc. saved at £5 each ...	£19,630
3,926 × 25 = 93,150 cases of sickness prevented at £1 each	93,150
2,121 persons, value of labour at £19 10s. for 10 years	413,595
Total saving in thirty years ...	£531,375

In this case £267,665 had been expended on all the public works, and they had effected a saving equal to £531,375, so that in a short space of twenty years a sum exceeding by 95% the total expenditure for works executed and the purchase of freehold property has resulted from the prosecution of sanitary measures."

In this calculation it will be noticed that Mr. Baldwin Latham takes no notice of the economic result arising from the increased longevity of the community due to improved sanitary conditions, which will be referred to later on.

Now if we apply Mr. Balwin Latham's process to the case of the City of Sydney for a period of fifteen years since 1883, allowing for the cost of funerals £7 each instead of £5, to meet local conditions, and in the matter of saving by reason of the escape of sickness, thirty cases for every life saved instead of twenty-five, and £2 as being a moderate value of the results in each case, and accepting the mean value of labour for men and women over and above maintenances as extracted from the Statistical Register as being £32 10s. for each case, we arrive at the following:

Average death rate 1871 to 1885	21·02	per thousand
" " " 1886 to 1900	15·38	"
" saving per annum ...	3·64	
" population, 1886 to 1900	411·762	

Lives saved during that period

$411.762 \times 5.64 \times 15$ ... 34·835

Proportion of adults over 20 years 53% by Coghlan

" " " 60 " 4·4% "

Effective lives ... ...48·6%

Therefore $34.835 \times 0.486 = 16{,}930$ persons saved in the full vigour of life.

34,835 funerals at £7...	£243,845
$34{,}835 \times 30 = 1{,}045{,}050$ cases of sickness prevented at £2	2,090,100
16,930 vigorous lives, industrial value £32 10s.	8,253,375
Total saving in 15 years ...	£10,587,320

Equal to £21 11s. 7d. per head of the present population or £304 per head of lives saved, against which the sum of £7,664,000 has been spent on water supply and sewerage, the result being equivalent to practically a ten years purchase of the works.

Although the view here presented by Mr. Baldwin Latham of the monetary value of sanitary engineering works is a truly astounding one, it by no means overstates the case, but on the contrary overlooks many material benefits for which credit may fairly be taken: Firstly, there is the additional duration of life due to improved sanitary conditions which is general over the whole community, and is a separate benefit from that conferred by the reduced death rate, for in addition to the lives saved, the rest of the community have their lives lengthened: this increase of man's allotted space has been very marvellous of late years, and it has been carefully recorded in older countries, but the author has been unable to ascertain the rise of longevity in this country during late years, and therefore reluctantly leaves it out of consideration, but in addition to the items valued by Mr. Baldwin Latham, the author adds the following:—

(*a*) Increased value of house property.

(*b*) Deterioration of merchandise saved owing to clean well watered streets.

(*c*) Preservation of street surfaces by watering.

It might be noted in reference to items *b* and *c* that the City of London in 1880 spent £200,000 in watering the streets, and it was reckoned that £200,000 was saved to the shopkeepers by the outlay; as the population of London is ten times the population of Sydney, the sum I have set down in my estimate further on, as the saving per annum, is just one-tenth of the saving in London.

(*d*) Saving to municipal authorities in scavenging.

(*e*) Increase of the population by the progeny of lives saved.

(*f*) Saving to commercial concerns by the use of pure water for boilers and engines.

In connection with this item it may be mentioned that in large boilers used for commercial purposes the deposit of scale is a nuisance, and its removal a costly matter. It is well known that the presence of scale increases the consumption of fuel on account of its non-conducting properties, and it has been demonstrated by experiments that $\frac{1}{16}$th of an inch of scale requires the expenditure of 15% more fuel in the furnaces, and $\frac{1}{4}$ inch of scale 60% more fuel. Further, the presence of scale necessitates the increasing of the heat in the boiler plates, which injuriously affects them by reducing their tenacity: experience shows that when scale has accumulated to a thickness of $\frac{1}{2}$ an inch, it requires 700% of heat in the boiler to raise the steam to a temperature of 320° Fahr. with a working pressure of 90 lbs. which introduces a tensile stress in the plates far in excess of the mean maximum tenacity of 65,000 lbs. per square inch of sectional area. Thus hard water or water containing solids is bad for feeding boilers, and means increased

coal bills and injured boilers, and hence the supply of good pure water to a large commercial community employing much machinery is one of the most important economic effects of sanitary services. Again pure water means to the railway engineer that engines can haul greater loads whilst the boilers do not require to be cleaned so often; one instance may be mentioned in this State where in the case of the tramways at Broken Hill, it is well known that the water used in the motors was so impregnated with slime and mineral impurities that it was often difficult to get the motors to work.

(*g*) Saving to the public in the consumption of soap, due to the softer quality of the water.

In connection with this item it may be mentioned that London water contains 15 to 20 grains bicarbonate of lime to the gallon, which means that each days supply holds 182 tons of soap destroying material, or 66,340 tons per annum: in Glasgow they calculate to have saved £40,000 a year since the supply was obtained from Lake Katrine. In Birmingham when the new supply is available, they expect to save £120,000 per annum, reckoning soap at the moderate price of 2½d. per lb., and doubtless there are many other instances which could be cited.

Now if the calculation is revised so as to include the above we have in the case of Sydney:

34,835 funerals at £7	£243,845
34,835 × 30 = 1,045,050 cases of sickness prvented at £2...	2,090,100
16,930 vigorous lives, industrial value £32½	8,253,375
(*a*) Increased value of house property assessed at 5% on £40,000,000 = £2,000,000 at 5% interest = 15 years £20,000	1,500,000
(*b*) Deterioration saved on merchandise 2% on £1,000,000 × 15 years	300,000

(c) Preservation of street surfaces by watering 1% on 100,000 for 15 years ...	15,000
(d) Saving to municipal authorities in scavenging, 2½% on all expenditure (Burwood experience) £400,000	10,000
(e) Increase of population by progeny of 16,930 vigorous lives allowing 27·6 births per 1,000 (Coghlan) 7,005 lives valued at £16 5s.	113,831
(f) and (g) possibly do not apply to Sydney.	
	£12,526,151

That eminent sanitarian Capt. Douglas Galton, R.E., in his presidental address to the Sanitary Institute of Great Britain, makes an estimate of the economy resulting from sanitary works as follows:—

He compares the mortuary rates at Westminster with those in the Westminster Improved Dwellings which shows the mean age at death for males of the wage earning class who died after the age of 20 as being 47·6 years for the former, and 59 for the latter, the result being about 11 years additional duration of life owing to improved sanitary surroundings, and consequently a profit to the community by reason of increased earning power. By referring to Neisson's tables, he finds that 6% would be a fair average deduction for sick time between the ages of 47 and 59, and he therefore takes the increased earning power as that due to 11 years less 6% or 10·34 additional years of life. He allows £1 per week for the value of this earning power for each head of a family, and calculating for 10·4 years upon a 4% basis he finds the *present* value of the increased earning power. Now if we apply this method to the case of Sydney, assuming five persons to each family for a population of 411,762, we have 82,352 families, the value of whose increased earning power for say 10 years would be in 15

years on a 4% basis equal to £23,778,150. In this method the values of the benefits due to increased longevity and reduction of the death rate are combined, and there is no doubt that the wider view by Capt. Douglas Galton of the accrued benefits of sanitation is the correct one.

A comparative statement of the economic effect for Sydney by the three different methods quoted is as follows:

1. By Baldwin Latham ... £10,587,320
2. By Captain Galton £23,776,150
3. By the author £12,526,151

But whatever may be the actual money value of the improved conditions of life due to sanitary works it will be quite safe to adopt the lowest computation by Baldwin Latham which gives a 10 years purchase of the works.

The local authorities of any town contemplating sanitary works may apply these results to their own case by forecasting :—

1. The number of lives saved per 1,000 by probable reduction of death rate, say in ten years after completion of works, which by adopting the mean saving of the thirteen cases illustrated in the appendix "A" may be assumed to be 9·05.

2. Forecasting the mean population for same period.

3. Calculating with 1 and 2 the total saving of life for ten years.

4. Calculating money saved by Baldwin Latham's system which would be about £135 per head of lives saved.

5. Adopting the money thus saved as the capital expenditure justified by the results to be obtained.

In this way they can compile an approximate balance sheet shewing the profits they may reasonably expect from the expenditure.

An inspection of Appendix "A" shews that the average cost per head, of the cases cited, for water supply and sewerage works is £10, of which amount the average proportion spent on water supply is £5 14s. 10d., and on sewerage £4 6s., so that any local authority can arrive at the approximate cost of such works by using those figures.

As for example, take a town of 20,000 inhabitants, by Baldwin Latham's method $\frac{20{,}000 \times 9{\cdot}05}{1{,}000} \times 10$ years $\times$ £135 £244,350 saved in ten years. By average cost in Appendix "A" 20,000 × £10=£200,000 total outlay of which £104,000 is the proportionate expenditure required for water supply and £96,000 is the proportionate expenditure required for sewerage works.

In conclusion I would draw attention to one aspect of mortality that unfortunately sanitary works does not appear to have ameliorated and that is infantile mortality. The British press has recently been drawing attention to the appalling loss of life amongst children of tender age; it is asserted that during the quarter including July, August, and September 1901 the number of children under the age of one year who died in the Scotland division of Liverpool was at the rate of 659 per thousand births; in the Exchange Division of the same city the number of deaths was 630; in the Everton Division the number was 436. In our own City of Sydney the number of deaths of infants in 1901 under one year of age was 127 per 1,000 births, the lowest record being in one of the suburbs 20 per 1,000, and the highest in one of the suburbs, viz. 272 per 1,000. In Melbourne the mean infantile death rate under one year of age for the years 1873 to 1898 inclusive was 158 per 1,000.

One notable economic effect due to sanitary services is the balancing of the losses in population due to the decrease

in the birth rate which during the last twenty-five years has been observed over the whole civilized world, and which in Australia has been of such a startling character, as to attract universal attention. Diagram 6 illustrates by coloured curves the decrease of the birth rate in various countries during the last twenty-five years, and the compensation due to lives saved by sanitary services in the case of Sydney Metropolitan District is set off by a vertical line at the right hand side of the diagram which fixes the compensation gradient for reduced births by the balancing of the two forces. During the period of 15 years under review in Appendix "A" for Sydney, the birth rate has fallen 18·08 per 1,000 of the population, whilst the death rate has been reduced by 5·64, and during the period of 25 years under review in Appendix "A" for Melbourne, the birth rate has fallen 8·22, whilst the death rate has been reduced by 5·42 per 1,000 of the population, so that although the decreasing birth rate is a question of very grave importance for a young State with enormous tracts of land awaiting development, we can derive some comfort from the set off of a decreased death rate and increased longevity due to sanitary services. Although much has been accomplished during the past fifty years in the saving of human life by sanitary works, there still remains great scope for further effort, and if the next fifty years cannot show such rapid progress as the last half century has produced, yet we cannot doubt but that there will be some progress to record, and if the age of human life is extended by only a year, or a fraction of a year, or if the present death rate can be reduced by only the tenth part of a life, still it will be an achievement worthy of our best endeavours and an appreciable economic effect of sanitary works.

J—Aug 5, 1903.

APPENDIX "A."

Name of Places.	Period of Construction of Works.	Average population during period under review.	Population served by works last year period named.	Average Mortality per 1,000 Before construction of works.	Average Mortality per 1,000 Since construction of works.	Lives saved in 20 years.	Lives saved per 1,000 owing to construction of works,	Expenditure on Sanitary Works. Water Supply. £	Sewerage. £	Total. £	Cost per head of Population. £ s. d.
1. Sydney	1885 - 1900	411,762	490,630	21·02	15·38	46,360	5·61	4,164,000	3,300,000	7,664,000	15 12 5
2. Melbourne ...	1876 - 1901	372,000	498,000	20·21	14·79	40,324	5·42	3,715,203	3,314,324	7,229,527	14 10 4
3. Adelaide	1885 - 1900	100,000	148,000	18·39	14·70	7,380	3·69	1,536,000	609,495	145,493	14 10 0
4. Christchurch	1875 - 1889	16,785	...	30·40	9·77	6,880	20·63	unknown	127,000		
5. Brisbane	1876 - 1900	47,000	65,263	25·42	17·93	7,040	7·49	642,819	nil	642,819	9 10 10[1]
6. London	1851 - 1890	3,300,000	4,200,000	24·80	19·50	349,800	5·30	15,000,000	13,250,000	28,250,000	6 14 6
7. Birmingham	1860 - 1900	500,000	710,000	24·90	19·40	55,000	5·50	3,457,332	427,000	3,884,332	5 9 4
8. Cardiff	1850 - 1870	33,000	50,000	33·20	22·60	6,980	10·60	*300,000	200,000	500,000	10 0 0[2]
9. Croydon	1848 - 1855	43,912	60,000	24·03	19·56	3,926	4·47	161,958	163,059	325,017	7 8 0[3]
10. Glasgow	1870 - 1900	800,000	1,000,000	56·00	23·00	460,000	23·00	3,525,000	2,250,000	5,775,000	3 16 6
11. Brighton	1872 - 1890	108,000	121,000	22·01	15·04	15,055	6·97	356,000	227,075	583,075	4 15 9
12. Buenos Aires	1887 - 1893	474,000	560,000	32·00	24·30	72,966	7·70	4,551,410	5,504,044	10,056,454	17 19 2
13. Calcutta	1866 - 1899	400,000	843,000	50 app.	38·8	89,600	11·20	3,762,000	*2,500,000	6,262,000	7 8 6
						1,161,311	9·05 avge				10 0 0[4]

REMARKS—* Approximate. [1] Water Supply only. [2] Since 1870 the total on water £1,184,000. [3] Old system of Sewers £1,000,000. New system of Sewers £1,250,000. [4] Average cost per head for Water Supply and Sewerage.—Average cost for Water Supply £5 14s.; ditto for Sewerage £4 0s. 6d.

I wish to express my thanks to Dr. Mailler Kendall, the Medical Officer of the Water and Sewerage Board, and to Col. Holmes the Secretary, for their assistance and for giving me access to books and documents in their custody, also to the Government Statists of Victoria, Queensland, South Australia, and New Zealand, and Mr. Henderson City Surveyor of Nelson, New Zealand, for supplying me with a large number of statistics; I also wish to acknowledge my indebtedness to Mr. Coghlan's Statistics of New South Wales, the minutes of the proceedings of the Institution of Civil Engineers, the proceedings of the Sanitary Institution of Great Britain, and the Engineer, and many other journals, for without their valuable assistance I would have been unable to compile this paper.

SAND-DRIFT PROBLEM OF ARID N. S. WALES.

By COLIN J. McMASTER,

(Chief Commissioner of Western Lands)

[With Plate X.]

[*Read before the Royal Society of N. S. Wales, August 5, 1903.*]

MR. MAIDEN in his valuable paper on the "Sand-drift Problem of New South Wales," read before this Society last month, indicated that sand encroachments from the sea can be controlled, but up to the present time no recorded attempt appears to have been made to deal with what may be considered the more important question of the moving sands of the extreme western parts of New South Wales, which in this respect may be regarded as typical of Western Queensland and generally of Central Australia.

Unfortunately no careful observations appear to have been made to ascertain whether what is popularly known as the "Drifting Desert Sands" are approaching the better and climatically more favoured lands in the Central and Eastern Territorial Divisions of the State of New South Wales. It is well known that the western sands are blown about by the winds, and the fact that red dust from the arid regions is carried hundreds of miles by the westerly winds is prima facie evidence that at times the sand also is blown to the eastward. The rate of progress in this direction may be so slow as hitherto to have been almost imperceptible, but the opinion is ventured that during seasons of drought the extent of sand-covered country is considerably augmented, the direction of the extension of the area being governed by the prevailing winds, and although the stronger soils in the vicinity may be improved by a light top dressing of sand, it may so happen that they will in course of time be covered to such a depth as to render them comparatively valueless.

That the imperceptible eastward trend of the sands has not been specially marked in the past, is not sufficient ground for assuming that an equally slow rate of progress will take place in the future, because up to within recent years the land was more or less covered with vegetation, but now to an alarming extent vegetable growth of all kinds has disappeared, and in the future the sands may drift in every dry season instead of during periods of prolonged and excessive drought, such as this State has recently passed through.

Overstocking undoubtedly reduces the surface of the country to a condition that leaves it at the mercy of the disastrous westerly winds, the lighter and more valuable portions being blown away completely, while the raw sand —usually red but sometimes white—left behind accumulates

into drifts, leaving bare patches of stones or clay to mark the place that once was covered with soil and valuable fodder plants.

Mr. Maiden's suggestion that indigenous plants should be planted and conserved for the purpose of checking sand encroachments is a most valuable one. If native plants can be conserved and plantations of the kind recommended by him can be successfully formed, the sands could no doubt be kept within reasonable bounds, but the cost of making plantations would be out of all proportion to the productive capacity of the extremely low grade country in which the sand-drifts occur and which embraces such a very large extent of the Western Division of New South Wales. The pastoral occupiers in these localities could not possibly afford to meet the heavy expenditure that would be required for plantation purposes, and unless the work was carried out by the State there is little prospect of its being done at all, or at any rate until such time as the stocking of the country can be regulated, so that comparatively large quantities of stock in good seasons, and none or very few in times of drought, may be kept upon the land. At present the conditions surrounding the pastoral industry in the remote interior are such that in times of drought it is frequently impossible to remove stock by road to more favored localities because of the absence of both feed and water on the intervening stock routes. The result is that the country remains overstocked at a time when it is least able to bear it, and almost every particle of edible vegetation is eaten and trampled out. In cases of this kind the pastoralist is the victim of circumstances over which he has practically little control, and the evil effects of the large number of stock upon the land, under the circumstances mentioned, is greatly intensified by rabbits which effectually destroy every remaining vestige

of vegetation. In seasons of good rainfall pasture grows in such abundance that it is practically impossible to overstock the country, but in times of drought rest alone can save the Western Districts from again becoming the "Heartless Desert" that Sturt described it to be in 1845.

With the return of wet seasons it is believed that the sandy areas will once more be sufficiently clothed with vegetation to check the further spread of the drifting sands; but in order to prevent the country from further deteriorating in this respect, it will be necessary to provide the western graziers with railways within easy reach and at low freights for the removal of stock in dry seasons. In addition to this, ample supplies of water should be conserved on all public highways and on all roads leading to and serving as feeders to such railway. If these be provided, it is believed that the stock owners will be able to regulate the quantity of stock their holdings are capable of carrying with safety, and in doing so a condition of affairs will gradually be brought about that will justify the individual as well as the State, in giving effect to the valuable proposals by Mr. Maiden, in fact it may so happen then that nature will assert itself to such an extent that no artificial assistance, other than the railways referred to, will be required to keep the drifting sands in check.

Without railways to relieve the country of stock in times of drought, any attempt to cope with the Sand Problem of the West is regarded as almost hopeless, but with their assistance in the manner indicated, the question will be reduced from one of extreme difficulty to one of comparative simplicity. It is not contended that railways of this kind will from the commencement be direct revenue producing concerns, but there can be little doubt that the amount the State has lost through the depletion of the western flocks and herds, that might have been saved by railway

communication, would have more than covered their cost. It is a well-known fact that last year, one of our leading pastoralists removed by rail about 100,000 sheep that could not be travelled by road. If the railway had not been available for this purpose, this large number of sheep would no doubt have completely eaten out the country, and after devastating it would themselves probably have perished. The effect of relief of this kind on country that may have a tendency to develop drifting sands, can be more easily imagined than described.

That Mr. Maiden's paper will have the effect of drawing public attention to the necessity for studying the Sand-drift Problem of the West, there can be little doubt; in fact, Mr. A. W. Mullen, (attached to the Staff of the Western Lands Commissioners) who heard Mr. Maiden's paper read, became so interested that immediately on his return to Bourke he forwarded to the Commissioners a comprehensive report accompanied by sections of levels taken by himself, of a drifting-sand hill in the County of Landsborough on the western side of the Darling River. He also forwarded samples of the sand taken from the hill, analyses, for which the author is indebted to Mr. Guthrie, F.I.C., F.C.S., together with extracts from the report referred to on nextp age, and reduced sections of the levels see *Plate* 10.

Attention is invited to the similarity that exists between analyses *A* and *B*, indicating, in the author's opinion, that for the purpose of supporting plant life the hardpan or subsoil remaining after the surface soil has blown away is not inferior to the surface soil.

In furtherance of Mr. Maiden's views, it is thought that scientific observations should be made in order to ascertain beyond doubt whether the western sands are really encroaching on the better lands to the eastward, and what

the probable effect of such encroachment, if any, upon the rest of the State is likely to be.

A vast amount of valuable information with regard to the western sands may be obtained from the Report of the Royal Commission, appointed 11th August, 1900, to inquire into the condition of the Crown Tenants in the Western Division of New South Wales. The author, who was President of the Commission referred to, had exceptional opportunities for making himself familiar with the subject under consideration.

Analyses of samples of soil obtained by Mr. Mullen from Cuttaburra Creek sandhills, County Landsborough, west of the river Darling in New South Wales:—

A—Surface soil supporting vegetation, (Yarran and other trees).

B—Hardpan or subsoil remaining after surface soil has been blown away.

C—Drifting sand.

	A	*B*	*C*
Moisture	0·588	0·687	0·474
Volatile and organic matter	2·750	2·370	0·90
Nitrogen	0·043	0·025	0·014
Soluble in Hydrochloric Acid.			
Oxides of iron as Ferric oxide (Fe_2O_3)	1·280	1·333	0·560
Alumina (Al_2O_3)	1·315	1·622	1·030
Lime (CaO)	·190	·212	·156
Potash (K_2O)	·125	·145	·100
Phosphoric acid (P_2O_5) ...	·060	·048	·047

EXTRACTS FROM MR. A. W. MULLEN'S REPORT, W.L.B. 6771 (Dated 30th July, 1903.)

Referring to the country from west of the Paroo River eastwards to the Darling River, extending about 100 miles south from the Queensland border, Mr. Mullen, says:—

"Under the influence of westerly drought winds, the soil—loose and dry under the combined action of stock and drought, and absence of vegetation—is lifted and carried in clouds of dust in a north-easterly direction, the density of the dust-storms depending upon the force of the wind, and during the past five years of drought, occasionally the dust has so obscured the sun at midday, that it became necessary to light lamps indoors to carry on business, and I have frequently been caught in such storms whilst travelling, and on two such occasions I was unable to see the horses in the buggy in front of me through the dust. Work under these conditions is almost impossible, but fortunately the severe dust-storms are not of frequent occurrence.

"The dust and sand carried by these wind-storms is reddish in colour and its course is arrested by brush or log fences and yards, wire netting fences, or fences against which débris has collected. In places where the wind has a clear sweep across open ground, the average height of the sand silting against brush yards or netting fences is about four feet."

Referring to some improvements that were affected by the drifting-sands, he says:—

"These siltings, together with the silting up of a running artesian bore drain, occurred to the north-east of an artificially cleared cultivation paddock, about 100 acres in extent, the soil being blown off the exposed surface of the ground, and carried about half a mile on to the buildings, drain and yard. Shifting or rolling sandhills are almost invariably found on the eastern side of open country or land cleared of its natural covering of vegetation. The sandhill of which I enclose levels, is an isolated strip of red sandy soil surrounded by the Cuttaburra Creek, a watercourse of level grey sedimentary clay, liable to inundation during high floods.

"The isolated sandhills to the east of open country or clay pans are the only really shifting sands, the movement being in an easterly direction. During windy drought a hard red soil or sand base is left on the western side of the sandhills, and the eastern side presents a steep loose sandy face, cliff-like in appear-

ance. The sandhills are rarely more than a quarter of a mile in width by two miles in length, and the shifting occurs only in seasons of severe drought; the tops are a series of mounds like billows, which in good seasons are changed by the action of rain and moisture, and herbage and grasses grow on the sides of these hills. If the natural scrubs and bushes in the area mentioned are destroyed indiscriminately and removed from the surface of the ground, windswept country will occur, especially where rock or stone is close to the surface, and the result will be disastrous, as nothing will grow upon the bare subsoil. Ringbarking and scrub-cutting should be strictly supervised, and where the timber is thin, it should not be ringbarked.

"For binding these loose sands the local drought-resisting growths are most suitable, these consist of spinifex, red soil roly-poly, button, wire grasses and budda bush It is almost impossible to kill the latter scrub, rabbits and drought have no effect upon it, and if cut down it comes up thicker than ever. During the severe drought of the last five years, the scrubs have survived when thousands of acres of pine, box, coolibah, and other large trees have perished—many of the dead pines being up to one foot in thickness."

The ABORIGINAL FISHERIES at BREWARRINA.

By R. H. Mathews, L.S.,

Associé étranger Soc. d'Anthrop. de Paris.

[With two Illustrations.]

[Read before the Royal Society of N. S. Wales, August 5, 1903.]

The town of Brewarrina is built upon the left bank of the Darling River, parish of Brewarrina, county of Clyde, New South Wales, and is at present the terminus of the railway into that district. Near the northwest extremity of the town, at a bend in the Darling River, there is a low bar of Desert Sandstone across the channel, forming a natural weir or dam when the river is low. Above the bar there is a long stretch of deep water, never known to go dry, called Gurrüngga by the natives. As soon as the water in the river rises to the level of the rocky bar, it flows over, and forms a series of shallow rapids for about a quarter of a mile, in which distance it is said to fall eleven feet. When the river is in flood, the channel is filled to a sufficient depth to allow flat-bottomed steamers and barges to pass over the rocks. These barges carry merchandise on the up journey, and wool and other produce on the downward trip.

In examining the channel of the river at the site of the rapids, we find evidence of the sandstone outcrop at this spot having been much wider and higher in ancient times than at present. All the way along the southern bank of the river from the present bar downward for about fifteen chains—and at a few places on the opposite bank—the Desert Sandstone is exposed. Here and there on the river floor, within the same distance, isolated masses of this rock, which have withstood the erosion of flood-waters,

are still standing. The average width of the bed of the river is about five chains at this place.

From these indications we may safely infer that the river, in the course of a long period, has cut its way through about fifteen chains of the Desert Sandstone, that is, from about the point *D* on the diagram upward to the existing bar. Mr. R. Daintree was the first to name rock of this description. Speaking of "horizontal beds of coarse grit and conglomerate," he adds, "I have called this upper conglomerate series 'Desert Sandstone,' from the sandy, barren character of its disintegrated soil, which makes the term particularly applicable. . . The denudation of the Desert Sandstone since it became dry land, has been excessive."[1] Rev. J. E. Tenison-Woods,[2] in speaking of this kind of rock, says, "Wherever met with, it bears marks of being much denuded. Water seems easily to have broken it up. The age of the Desert Sandstone may be the equivalent of the Upper Cretaceous."

At the western extremity of the outcrop of Desert Sandstone, about the point *F* on my diagram, some schists are met with, for a description of which I will quote from the Report of Mr. E. F. Pittman, who has visited that district: "In the banks of the Darling, at the western end of the town of Brewarrina, Palæozoic slates and schists, with interbedded quartz veins, occur. These schists are inclined at a high angle, and are probably of the Upper Silurian age. These rocks in the river bank are overlaid by horizontal beds of Desert Sandstone, of the Upper Cretaceous age."[3]

During the progress of cutting out the river channel as above suggested, fragments of rock of various dimensions were worn off and broken up by the water, and formed into

[1] Quart. Journ. Geol. Soc., (London, 1872) Vol. xxviii., p. 275.
[2] "The Desert Sandstone"—Journ. Royal Society, N.S.W., Vol. xxii., pp. 291 and 296.
[3] Ann. Rep. Dept. Mines, N. S. Wales, 1902, p. 119.

boulders. After a long interval, the channel of the river at this spot became strewn with boulders of different sizes. At some time subsequent to this period, the aborigines availed themselves of this building material and erected those interesting structures called by the white population of the river "The Native Fisheries," but which are known to the blackfellows as "Ngūnnhu."

Amongst other towns on the Darling River, I visited Brewarrina in 1901. The great drought was then at its worst, and the river had ceased to run, leaving the site of the aboriginal fisheries quite dry. I took advantage of this opportunity to make an accurate survey, with chain and compass, of the principal fish-pens still in existence.

Most of the aboriginal population of the district have died out, and the few blacks and half-castes who are left are settled upon an Aboriginal Station, under Government management, about six miles up the river from Brewarrina, where the aged people and children are fed and clothed at the expense of the State. Under these circumstances, and the natives being naturally an indolent race, they have allowed the fishing-grounds of their forefathers to get considerably out of repair, and many of them have been damaged by floods, or knocked down by steamers and barges navigating the river.

In the olden days when the natives were numerous, the fishing-pens were maintained in good working order, in anticipation of the spawning season and also of freshets in the river. At times when the stream was low, or the channel altogether dry, and the stone dykes were fully exposed, the men set to work and repaired such damage as might have been occasioned by trees and other débris carried down during floods. On such occasions new pens were sometimes added.

I will now endeavour to describe the fish-traps and their construction. The river-floor at this point consists of immense numbers of loose stones, ranging from twenty pounds to a hundred weight, with others of greater dimensions. The aboriginal builders collected large quantities of these stones and erected walls, in the way many of our farmers about Kiama used to build stone dykes or fences around their farms. These walls were erected in a substantial manner, being wider at the base, where also the larger stones were used, and tapering upward to the top. The stones were merely laid in position, without mortar or dressing of any kind, forming a structure sufficiently strong to resist the force of the current. The large stones used in the foundation or base of the wall were rolled into position, whilst the smaller ones were carried by the builders. Areas were enclosed in this manner, varying in dimensions from that of a small pond almost down to the size of a plunge bath, the walls of one enclosure being common to those around it, forming a labyrinth of inextricable windings. These enclosures were continued right across the channel from bank to bank, and occupied all the suitable portions of the river floor for about a quarter of a mile along its course. Some of the pens or traps were long and narrow, others nearly circular, whilst others were irregular in shape, according to the formation of the bed of the river, and the facilities for obtaining the heavy building material close at hand.

The level of the water was observed while the river was running, and owing to the unavoidable irregularities of the bed, the walls of some of the pens were built higher than others. Again, when the water was low, or during a small freshet, only a portion of the channel and the pens contained in it, could be utilized for fishing operations, whilst certain pens on higher ground could not be used at all, owing to

insufficiency of water. The average height of the walls varied from two to three feet. They were about eighteen inches wide at the base, and the top was surmounted by a single course of stones.

During the early spring months of the year, or at any time when there was a fresh in the river, the fish travelled up stream in immense numbers. The stone pens or traps had their open ends towards the direction from which the fish approached. The aboriginal fishers, men and women, were on the look out, and as soon as a sufficient number of the finny tribe had entered the labyrinth of traps, the openings were closed up by means of large stones which had been placed alongside ready for use. If the opening was too wide to be thus blocked up by stones, a number of natives posted themselves across it to prevent the egress of the fish. The natives next entered the pens and splashed the water with their hands or feet, thus frightening the fish into the smaller enclosures, where they were more easily caught. Any unusually large fishes which might be in the "haul," were killed as speedily as possible, because they at once commenced swallowing the smaller ones collected in the pens. These "big-fellow fish" were generally speared by the young men, as they first entered the enclosures, before they had time to do any damage.

It appears from the foregoing description that the fish, in coming up the river, were intercepted by the outliers or "wings" of this maze, which stretched from bank to bank; they entered the larger enclosures, from which they were chased into smaller and smaller pens, much in the way that sheep are driven into "catching-pens" at shearing time, or cattle into the "killing yard." In driving the fish through the different yards, some were killed by spear or club as opportunity offered, going along, but on arrival at the smallest pens all the fish were caught and killed. The

larger fish were speared, or killed by a club, but the smaller ones were caught by hand, the fisherman passing his finger through the gills and inserting a cord, on which he carried as many fish as could be dealt with in this manner. My old native informants told me that none were left in the yards, because if they got away they would warn all their fellow-fish not to go into such a trap in the future. One old man stated the same rule was followed in netting emus when he was a boy. Great care was taken to prevent the escape of an emu from the net, lest he should tell other birds about the ingenuity of their enemies.

Each division of the tribe, and the families composing it, had their own allotted portion of the fishing grounds, and every pen or trap had a name by which it was known and spoken of among the people. The following are a few of these aboriginal names:—Mirrā'gan, Gū'na, Thau'ia, Il'prūnya, Buddhau'inga, Giwirri, Ngiddēri, Gŭmboar'o, Mu'arba, Thulūr'digana, Būragūman, Būrugūngal', Dhau'-danbaia, Mogēl', Goāra, Wirridung-kunya, Wāgurma, Bau'andanna. In the lowest portion of the river bed, where the water has the most fall, and consequently runs the swiftest over the rapids, is called by the natives "Wirruwirrumba." Large rock masses, projecting high above the water, occupying their natural, undisturbed position in the channel, also had native names by which they were easily distinguished. The most remarkable of these large blocks of Desert Sandstone, which are chiefly near the southern bank of the river, are represented in their correct positions on the accompanping plan and their names given in the descriptive letter-press.

To enable the fishing operations to be proceeded with, it was necessary that the walls of the pens should be a little way out of the water, because when the flood rose above the tops of the traps, the fish could easily swim over them.

But when the pens in the lower portions of the river floor were submerged, those situated on a higher level, referred to in an earlier paragraph, could be availed of. When the river was falling these conditions were reversed—when the higher yards became dry, the lower ones were resorted to. In very uneven portions of the river bed there were several grades, to meet the exigencies of the rise and fall of the water.

The water of the Darling is never clear, but always of a greyish hue, owing to the light-coloured clays along its banks. This has given it the name, among poets and novelists, of "The old, grey river!" During long periods of dry weather, however, a good deal of the clayey matter held in solution sinks to the bottom and the stagnant water becomes somewhat clearer. In times of flood the water is muddy and of a slightly reddish shade, due to the storm water draining in from surface soils of that colour. Owing to this sudden change in the character of the liquid, the fish often flee before the advancing turbid stream, which appears to nauseate them. When such a fish-laden current reached the Ngŭnnhu at Brewarrina, the aborigines had the "up-stream" ends of their traps ready for action.

The Brewarrina fishing pens were situated within the territory of the Ngēumba tribe, who always mustered there in considerable numbers in the fishing season, or at other times when fish were expected to be plentiful. The same people did not remain there all the time, but when certain families moved away into the back country to hunt for kangaroos and other game, other families came in to the river, and participated in the piscatorial harvest. Although the fishing grounds were apportioned among specified people, as already stated, the ownership was not of the exclusive character existing among Europeans. For example, if a man were not present, his "claim" might be

worked by his relatives, such as uncles, brothers, brothers-in-law, nephews, or the like. Generally speaking, there were some straggling members of the tribe located about the fishing grounds all the year round.

The fishing season was sometimes made the occasion of inviting neighbouring tribes to join in their great corobborees, initiation ceremonies, or meetings for trade and barter. The people camped on either side or both sides of the river, because when the water was low enough to admit of the traps being used, it was quite easy for those who wished to visit friends on the opposite shore, to wade across the rocky bar.

The principal fish which formed the subject of operations at the traps were Murray cod, black bream, and yellow bellies. The black bream was the favourite fish among the aborigines as an article of food. The cod fish, so the natives told me, ramble down as well as up stream, and were caught in the pens at any time.

In the "History of the Fisheries of New South Wales," by Lindsay G. Thompson, published by authority of the New South Wales Commissioners for the World's Columbian Exposition, Chicago, 1893, an article was furnished by Mr. E. G. W. Palmer, in which at pp. 96–98, he briefly refers to the Brewarrina Fishery, and gives a photographic view of a portion of the structure. He erroneously describes the rocky bar as a "granitic dyke."

Explanation of Illustrations.

No. 1. Diagram.—The accompanying plan has been prepared by me from a detail survey which I made about a year and a half ago, and shews twelve chains of the channel of the Darling River, representing the dykes and pens still existing on the best preserved portion of the ancient fishing locality. Extending upward from *A*, see diagram, there are about eight chains more of the river floor containing

fragments of old fishing yards in different places, but they are of less extent and more disconnected than those I have selected for reproduction.

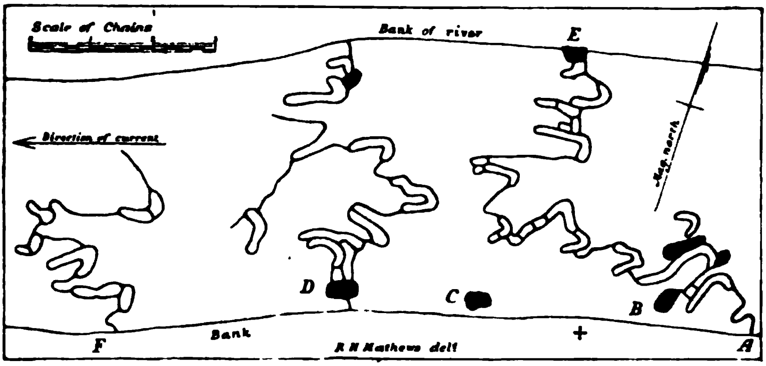

Diagram of the Ngūnnhu or Native Fish Traps in the Darling River at Brewarrina.

There is now a magnificent high-level bridge over the Darling about a mile above the fishery, but prior to its erection, loaded drays, travelling stock, and general traffic used to cross the river on the rocky bar already described, in consequence of which most of the pens in the vicinity of the bar have become dilapidated beyond recognition. In midstream, just below and adjoining the bar, is a small, low, rocky island, on which trees formerly grew, as evidenced by a few stumps still remaining. Within the recollection of the present natives, and also of old residents among the white people, the area of this island is less now than it was thirty or forty years ago, owing to the trampling of cattle and other stock. Between this island and the northern bank of the river, but somewhat lower down stream, are two other insular patches, but much smaller, with a few trees growing upon them. The oldest of the aborigines told me that the bar itself, and the margins of the little islands, were studded with catching pens in the olden times.

Near the southern bank, and at a few other places in the bed of the river, there still remain some masses of original rock which have withstood the ravages of time, and are shown in solid black on the diagram. The following are the aboriginal names of most of them:—*B*, see diagram, is called Muar; *C*, Kullŭr; *D*, Dherraginni; and *E*, on the northern shore, is known as Kirragurra.

The blank spaces on the diagram were in the olden days studded with fishing pens, of which the wreckage is visible in many places in the shape of scattered boulders and indistinct outlines of former enclosures. But the whole of the river floor was not occupied with the maze of traps. A waterway had to be left for the fish to travel up to the catching pens of families located higher up-stream, and for this purpose the most uneven portions of the bottom were selected because the least suitable for building upon.

The black, sinuous lines drawn upon the diagram represent the walls of the different pens, and groups of pens, with the "wings" or outlying walls which guide the fish into the enclosures. I have not shewn the openings into the traps, because they were sometimes made in one part of the wall, and sometimes in another, according to the part of the stream in which the "school" of fish were approaching.

At the point marked with a cross on the diagram, on the southern bank, which is rocky, between *C* and *A* there are about two dozen grinding places, worn in the rocks by the natives sharpening their stone hatchets. About three chains eastward from *A* there are a number of similar grinding places.

No. 2. Photographic View.—The photograph from which this zinco-plate has been prepared was taken from some high ground on the left bank of the Darling River a few yards easterly from the point marked *A* on the diagram, and faces

downward and diagonally across the channel, in a generally northwesterly direction, taking in a perspective view of most of the fishing pens shown on the diagram. The large horizontal rock on the left-hand side of the photograph is the same as the rock marked *B* on the diagram; and the rocky mass with an uneven top on the right-hand side of the picture corresponds to the long rock appearing in black on the diagram, due north of the rock at *B*.

Photographic View of the Native Fish Traps in the Darling River at Brewarrina.

The mark ×, visible on one of the trees on the opposite bank, in the middle of the picture, indicates the flood-level of the Darling River.

It is hoped that the two illustrations now supplied—the ground plan and the perspective view—together with the descriptive letterpress, will enable the reader to form a more realistic conception of the aboriginal fisheries at Brewarrina than has been possible hitherto.

THE SEPARATION OF IRON FROM NICKEL AND COBALT BY LEAD OXIDE (FIELD'S METHOD).

By T. H. LABY, Junior Demonstrator of Chemistry, University of Sydney.

[Communicated by Professor LIVERSIDGE, M.A., LL.D., F.R.S.]

[Read before the Royal Society of N. S. Wales, September 2, 1903.]

Review of Methods for the Separation of Iron from Nickel and Cobalt.

1. *Ammonium Hydrate and Chloride.*

The precipitation of ferric salts by ammonium hydrate in the presence of ammonium chloride gives an incomplete separation—according to Moore[1] an absolutely worthless one. No experimental work on the reprecipitations necessary for accuracy was found. Fresenius states three to be necessary. Baumhauer[2] is said to have found that ferric hydrate may occlude 27% of nickel and 48% of cobalt.

2. *Ammonium Carbonate* (*Schwarzenberg*[3]).

To the solution of the chlorides, containing ammonium chloride equal to twenty times the weight of the oxide of nickel present ammonium carbonate is added to a point specified in Schwarzenberg's paper, and quoted by Fresenius. The success of the method depends on striking a point difficult to ascertain. The method, however, is recommended by Fresenius and others. The writer in an analysis of a meteoric iron, found it to be a long and tedious separation; and the amount of nickel found being lower than by Field's method, partly owing to a slight loss in the pre-

[1] Chemical News, 1892, LXV., p. 75.

[2] Archives fur Néerlandaises, 1870, Vol. VI.—(Reference not verified.)

[3] Liebig's Annal. XLVII., p. 216; also Chem. Gaz., 1856.

cipitation of the nickel as sulphide and subsequent electrolysis. In this and the previous method the presence of much ammonium chloride makes the solution unsuitable for the immediate determination of the nickel by electrolysis. The solubility[1] of the sulphide in excess of ammonium sulphide may make the sulphide precipitation inaccurate.

3. *Basic Acetate.*

Kessler[2] uses a solution containing 1 gram of ferric iron per 500 cc., and adds 1 gram each of acetic acid and sodium acetate. The presence of much of the latter caused the iron to carry down manganese. Meineke[3] adds a small quantity of acetic acid and sodium acetate to a neutral solution and gives a short rapid boil. Mackintosh[4] believes ammonio-cobalt bases are formed which are peroxidised, finding five or six precipitations necessary; and that cobalt is more difficult to separate than nickel. Moore[5] says four precipitations are necessary. Brearley, who has done much to elucidate the acetate process, found, for a ratio first determined by Kessler, that the solution produced by carefully adding sodium or ammonium carbonate to a cool ferric chloride solution till incipient precipitation, contains then about seven-eights of the ferric chloride as "dissolved hydrate." He[6] adds sodium or ammonium carbonate to the cool ferric and nickel chlorides etc. till a slight permanent precipitate forms, 10 cc. of 5 E.[7] acetic acid, water to about a litre, then 10–12 cc. of ·36 E. ammonium or sodium acetate for each gram of iron present, and raises to the boiling point. He showed the separation is for total dissolved hydrate solutions most nearly complete when this *small*

[1] Terril—Chem. Gaz., 1857.
[2] Kessler, Ber. d. Deutsch. Chem., also C.N. XXVII., 14.
[3] Meineke, Zeit. Angew. Chem. 1888, 2, XIX., 282.
[4] Mackintosh—School of Mines Quarterly, July, 1887.
[5] Moore—C.N. 1892, p. LXV.. 75.
[6] Brearley—C.N. 1899, LXXIX., 194; C.N. 1897, LXXVI.. 210.
[7] Or 5 normal.

amount of acetate is used. Either the sodium or ammonium salts may be used. An increase of acetic acid tends to improve the separation, while an increase of acetate retards it; for example, taking 1·grm. of iron, ·1 grm. of nickel, 10 cc. of 5 E. acetic and 10 cc. of 4·4 E. ammonium acetate (122 cc. of ·36 E.) only ·0884 grm. of nickel was recovered. His results show the acetate may be better added to a boiling solution than a cold one, though this is opposed to the usual custom. Contrary to the opinions of Moore and Mackintosh his results would show cobalt to be more readily separated from iron than nickel is. The acetate and acetic acid mentioned first above, was insufficient for 1· grm. of iron in the presence of ·1 grm. of aluminium, but 60 cc. were necessary and only 98% of the nickel was then recovered. Nickel acetate though soluble in ammonium chloride is insoluble in acetic acid. Ferric acetate is decomposed at 100° C. into the hydrate and acetic acid.

4. *Phosphate Method.*

Cheney and Richards[1] precipitated the ferric iron by sodium phosphate in the presence of acetic acid. With more than 3% of nickel reprecipitation was necessary, 99% of the nickel was recovered. Moore[2] nine years later, apparently independently, published the same method recommending two precipitations for accurate work, but gave no test analyses.

5. *Electrolysis.*

Le Roy[3] deposits the nickel, cobalt, and iron from an ammonium citrate, sulphate, and hydrate solution, replaces it by a sulphate and hydrate one, and then reversing the current redissolves and reprecipitates the nickel and cobalt while the iron goes into suspension as ferric hydrate. No

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[1] Am. Journ. Sci., [3] XIV., 178 – 181, and C.N. 1877.
[2] C. N., 1886, LIV., 306.
[3] C.R., CXII., 772-3.

confirmatory results are given. Engels[1] states that nickel may be deposited free from iron if the latter is thoroughly oxidised by hydrogen peroxide. Foerster[2] finds iron to be deposited. Ducru[3] obtains the nickel, cobalt and iron (ferric) as sulphates, and electrolyses in the presence of the ferric hydrate precipitated by the free ammonia present. An irregular amount of iron, about ·5% of the total present is deposited with the nickel, partially insoluble in concentrated hydrochloric acid. Using the usual sulphate solution Neumann finds, contrary to Engels and Ducru, that with varying conditions of time and strength of current a quite irregular amount of iron is deposited (if more than ·1 gram of iron as ferric hydrate is present) which is tedious and inaccurate to determine volumetrically.

6. *The Ether Process.*

The solubility of ferric chloride, and insolubility of manganous, nickelous, chromic and aluminium chlorides in ether in the presence of hydrochloric acid was pointed out by Rothe[5] in 1892, who used it as a means of separating iron from cobalt, copper and these metals. Copper and cobalt partly in solution in the ether may be removed by shaking out the ether with 5·8 E. (S.G. 1·104) hydrochloric acid. A modification[6] of this is the solution of the chlorides (·4 grm.) in a minimum of water and 10 cc. of concentrated hydrochloric acid, the addition of 10 cc. of ether and the passing into it of hydrochloric acid gas at 0° C. The nickel is precipitated as the yellow chloride; the iron and cobalt are in solution. Adaptations for technical work, nickel steel and ores, have been published. Langmuir[7] precipitates the iron

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[1] Journ. Chem. Soc., Abs. 1893, ii., 192 Rundschau, 1896, 20 – 24.
[2] Ibid., p. 228.
[3] Bull. Soc. Chim., [3] XVII., (1897).
[4] Chem. Zeit., 1898, XXII., [72] 731 – 732.
[5] Abst. in C.N. 1892, LXVI., 183, Mitth. a. d. kgl. Tech. Versuchs. Anstalen, Berlin.
[6] Pinerua, C.N. 1897, LXXV. 193.
[7] Langmuir—Journ. Am. Chem. Soc. XXII., 1900.

with ammonium hydrate (the sulphuric acid present in the case of some ores etc. interferes with the ether extraction) before applying the separation of the chlorides. Acetone[1] may be added to the ether. The separation has been elucidated by Speller.[2] A minimum of hydrochloric acid of strictly 1·1 – 1·11 S.G. should be used to dissolve the chlorides, 5 cc. of ether being added per ·1 grm. of Fe. Two separations are made. The ether extraction process has yet to be tested as thoroughly as Kern tested it for iron from uranium. A slight alteration of the concentration of the reagents affects considerably the behaviour of the cobalt.

7. *Field's Process.*

Field[4] proposed the method examined in the following experiments. It is based on the precipitation by litharge of iron as ferric hydrate from a neutral solution of the nitrates of iron, nickel and cobalt. He gave two results of test analyses in support for nickel, but none for cobalt. Cheney and Richards[5] found "by far the best success was obtained in the use of the method given by Field," but Moore[6] says "Field's process . . cannot be recommended."

Experimental—Advantages of Field's Method.

An enquiry into the accuracy of Field's method was made, as it had distinct advantages over methods commonly in use, viz., a single precipitation of the iron, and the absence, after the removal of the added lead, of all reagents such as ammonium or sodium salts. When combined with the electrolytic determination of nickel and cobalt the method becomes more rapid than say a double precipitation of the iron by the basic acetate process and the precipita-

[1] Norris—Journ. Soc. Chem. Ind., xx., 6, 1901.

[2] Speller—C.N. 1901, LXXXIII., 124; Sargent—Journ. Am. Chem. Soc., Oct. 1899, 854.

[3] Journ. Am. Chem. Soc., XXIII., 10, 1902.

[4] C.N., 1859, I., 5.

[5] C.N. 1877, XXXVI., 161. [6] C.N., 1886, LIV., 306.

tion of the nickel and cobalt as sulphides. The electrolytic determination, which is highly accurate and convenient, cannot be readily combined[1] with the acetate process as some experimenters find that ammonium chloride is detrimental to the deposition of the nickel and cobalt.

Test Analyses.

In the following experiments, Table I., the amount of iron mentioned was taken in the form of a solution of the nitrate together with cobalt or nickel nitrates and evaporated in a porcelain dish on a water bath to dryness. It was found that the iron is precipitated as ferric hydrate most readily when the evaporation is stopped just before dryness, and the formation of a very basic nitrate of iron is avoided. The residue from the evaporation was diluted, brought to the boil and the lead monoxide added while the solution was boiling either in the dish or preferably in a conical flask. On the addition of sufficient lead oxide (six times the weight of the iron present) ferric hydrate separated out in a form which was readily filtered; but often the washing was most tedious, and some of the precipitate passed through the filter paper. In the first experiments hot water was used, but it was found better as would be expected, to wash with a solution of some salt, lead nitrate being the one used. The presence of a small quantity of ferric hydrate does not interfere with the accuracy of the electrolytic deposition of nickel and cobalt. The filtrate contains the nitrates of lead and cobalt or nickel. This lead was removed in some cases by evaporating the filtrate nearly to dryness, adding an excess of sulphuric acid, 50 cc. of 5 E. to every 1 – 2 grams of lead present, decomposing the nitrates, diluting, and finally filtering off the lead sulphate. In the case of experiments 5, 6, 8 and 9, Table I.,

[1] Electrolytic Methods of Analysis—Neumann; but compare Oettel, Zeitschr. f. Electro chem. 1894, I., 194.

6, 7, 8 and 9, Table II. the lead sulphate precipitated from the boiling solution by 50 cc. of 5 E. H_2SO_4 was filtered off without expelling the nitric acid. After adding an excess of ammonium hydrate these filtrates were electrolysed.

Standard Solutions of the nitrates of iron, nickel, and cobalt were prepared:—

Nitrate of iron from iron wire containing ·07% of carbon.

Nitrate of cobalt: 25 grams. of cobalt sulphate and 50 grams of ammonium sulphate were dissolved in water, made very slightly acid, sulphuretted hydrogen passed through the solution and the resulting precipitate removed. The filtrate was made alkaline with ammonium hydrate, and boiled for a long time in order to remove the iron as ferric hydrate. On electrolysis this solution gave a dull grey firmly adherent deposit which was weighed, dissolved in nitric acid and the solution made to a known volume. This purification would give a cobalt nitrate sufficiently free from all impurities, excepting nickel.

Nitrate of nickel[1] was prepared similarly. The flasks and pipettes used were calibrated against calibrated weights. Judging from the greatest difference between the values obtained for any one pipette in this testing the amounts of cobalt and nickel 'taken' are never inaccurate by more than ± ·0001 grm.

The equation for the *reaction* was found to be essentially

$$3\,PbO + 2\,Fe\,(NO_3)_3\ Aq = 3\,Pb\,(NO_3)_2 + Fe_2O_3\ Aq.$$

Thus the *lead oxide used* should be at least six times the weight of iron to be precipitated. In each of the test analyses, slightly more than six times as much lead oxide was used. An excess of 20 cc. of 17 E. ammonium hydrate was used in each electrolysis.

[1] Foerster—Zeit. Electro chem., 1897, IV., 160-165. C, Si, Cu, Mn, entirely absent from electrolytically deposited Ni, Fe, and Co in same proportion as unrefined material.

Table I.—Cobalt.

No.	Iron taken in gms.	Cobalt taken.		Cobalt found.	Error.
1	·004	·2289		·2293	+·0004
2	·004	·2289		·2290	+·0001
3	none	·2289		·2287	-·0002
4	·2	·2289	cobalt not completely removed by electrolysis.	·2253	-·0036
5	·2	·2389		·2266	-·0023
6	[·2	·2289	ditto,[1] ditto, ditto	·2178	-·0111]
7	·2	·2289		·2221	-·0068
8	·2	·0229		·0235	+·0006
9	·2	·0229		·0238	+·0009
10	none	·0458		·0466	+·0008
11	none	·0229		·0235	+·0006

[1] This filtrate though electrolysed all night and for three hours with ·8 ampères still contained cobalt as was shown by passing sulphuretted hydrogen.

Table II.—Nickel.

No.	Iron taken in gms.	Nickel taken.		Nickel found.	Error.
1	·004	·2149		·2145	-·0004
2	·004	·2149	ferric hydrate contained nickel	·2123	-·0026
3	none	·2149		·2147	-·0002
4	·2	·2149	iron ppt. by PbO from boiling sol.	·2114	-·0035
5	·2	·2149	ditto, ditto, by PbO in the cold	·2100	-·0049
6	·2	·2149	ditto, ditto, by PbO from boiling sol.	·2122	-·0027
7	none	·2149	Pb added and removed as sulphate	·2155	+·0006
8	·4	·0430		·0454	+·0024
9	·4	·0430		·0451	+·0001
10	none	·0430		·0439	+·0009
11	none	·0219		·6224	+·0005

Conclusions.

This method, requiring only one precipitation of the iron, though not so good as claimed by Field, is more accurate for cobalt than the basic acetate process; and as accurate for nickel—about 99% of the latter and rather more of the former being recovered. It can be very readily combined with the electrolytic determination of nickel and cobalt, (Gooch and Medway[1] using a rotating cathode, have accurately determined nickel by electrolysis with a current of less than thirty minutes duration.)

The author desires to thank Professor Liversidge for having given every facility for this research.

[1] American Journal of Science, 1903, xxv., p. 50.

POT EXPERIMENTS TO DETERMINE THE LIMITS OF ENDURANCE OF DIFFERENT FARM-CROPS FOR CERTAIN INJURIOUS SUBSTANCES.

By F. B. GUTHRIE, F.I.C., F.C.S., and R. HELMS.

[*Read before the Royal Society of N. S. Wales, September 2, 1903.*]

Part II.—MAIZE.

THE experiments here recorded are in continuation of similar ones with wheat[1] and were conducted in precisely the same manner. A description of the pots used and the manner in which they were filled and treated is fully given in the previous paper, and need not be here repeated. Mr. Maiden kindly set apart a space in the Botanic Gardens for the purpose of the experiments which were conducted in all details in the same manner as the preceding ones.

Nature of Soil.—The soil with which the pots were filled was a fairly rich garden loam mixed with nearly an equal quantity of a light sand.

The composition of the mixed soil was as follows:—

Moisture	... ...	1·13 per cent.
Organic matter	...	8·14 ,,
Nitrogen	... ...	·202 ,,
Soluble in strong HCl.		
Lime ...	... ...	·257 ,,
Potash...	... ...	·112 ,,
Magnesia	... ...	·069 ,,
Phosphoric acid	...	·107 ,,

Each pot received in addition 10 grms of superphosphate. Several check-pots were filled in exactly the same way with the exception that the deleterious substances were omitted.

[1] This Journ. xxxvi., p. 191.

All the pots were exposed to exactly the same conditions as to light, warmth, water, etc., throughout the course of the experiments.

Experiments with Common Salt.

Eight pots were filled with the soil and superphosphate together with the following quantities of common salt per 100 lbs. of soil:—

No. 41,	·10	per cent.	of NaCl.
,, 42,	·15	,,	,,
,, 43,	·20	,,	,,
,, 44,	·25	,,	,,
,, 45,	·30	,,	,,
,, 46,	·35	,,	,,
,, 47,	·40	,,	,,
,, 48,	·50	,,	,,

The pots were sown on October 24th, 1902, with 7 maize kernels in each pot, the surface being covered with a mulch of shredded cocoa-nut fibre and the soil kept moist throughout the experiment.

The following notes were made on November 3rd with regard to the germination:—

Pots 41 and 42 had germinated well.

In 43, 44, 45, the germination was retarded.

In 46 much, and 47 very much retarded, whilst in 48 the seeds did not germinate.

On November 21st the further growth of the plants was noted:—

In Nos. 41 and 42 the growth was fair, but quite markedly affected.

In No. 43 the growth was very strongly affected.

In Nos. 44, 45, and 46 the plants were dying and very nearly dead.

In No. 47 the plants were all quite dead.

As the growth was affected by the smallest quantity taken (Pot 41), three pots were resown on November 28th, with smaller proportions of salt :—

No. 49	with	·025	per cent.	NaCl.
,, 50	,,	·050	,,	,,
,, 51	,,	·075	,,	,,

All these germinated well and were growing well on January 15th, 1903, showing that a quantity of NaCl below ·1 per cent. has no injurious action on the growth of maize.

From the above it is concluded that the germination of maize is unaffected by the presence in the soil of sodium chloride up to ·2 per cent., and that between ·4 and ·5 per cent. prevents germination.

The growth of the plant is markedly affected by ·1 per cent. of sodium chloride, and plants will not grow in soil containing ·25 per cent. and upwards.

Experiments with sodium carbonate.

Eight pots were filled with soil, manured with 10 grms. superphosphate each, and sown with 7 maize-kernels on October 24th, 1902. The quantities of sodium carbonate previously added to the different pots were as follows :—

No. 52,	·10	per cent.	Na_2CO_3
,, 53,	·20	,,	,,
,, 54,	·25	,,	,,
,, 55,	·30	,,	,,
,, 56,	·35	,,	,,
,, 57,	·40	,,	,,
,, 58,	·50	,,	,,
,, 59,	·60	,,	,,

On November 3rd the following notes were made as to their germination :—

No. 52 had germinated perfectly.

In Nos. 53 and 54 the germination was slightly retarded, more so in 55 and 56; very much retarded in 57, whilst the seeds of 58 and 59 had not germinated.

The growth of all was more or less affected.

On November 21st the plants of pot 52 were growing well, though the effect of carbonate of soda was noticeable. This was somewhat more marked in 53, whilst in 54 the growth was strongly affected, and in 55, 56, 57, 58 and 59 the plants were all dead.

The conclusions drawn are the following:—Quantities up to ·1 per cent. carbonate of soda in the soil are tolerated by the maize plant, and are without effect upon the germination or subsequent growth. ·1 per cent. already acts as a poison to the growing plant, the effect of which is more and more marked up to between ·25 and ·30 per cent. at which point the plants die. The germination is slightly affected by ·2 per cent., and ·5 per cent. prevents germination.

Experiments with ammonium sulphocyanide.

Six pots were prepared as in the previous experiments with the following quantities of sulphocyanide, and sown on October 24th:—

No. 60,	·001	per cent.	NH_4CNS.
,, 61,	·002	,,	,,
,, 62,	·003	,,	,,
,, 63,	·004	,,	,,
,, 64,	·005	,,	,,
,, 65,	·006	,,	,,

On November 3rd, Nos. 60 to 63 had germinated well. In Nos. 64 and 65 the foliage had become spotted.

On November 21st, Nos. 60 to 63 were growing fairly, though all showed signs of the effect of the salt, and were not so vigorous as the check plants. Nos. 64 and 65 had recovered in colour but the growth was somewhat stunted.

Three more pots were sown on November 28th, containing somewhat larger proportions of sulphocyanide:—

No. 66, ·008 per cent.
,, 67, ·01 ,,
,, 68, ·02 ,,

Nos. 66 to 67 germinated fairly but slowly and not vigorously, and No. 68 was somewhat more retarded. Their subsequent growth (January 15th, 1903) was more strongly affected.

The results show that proportions of ammonium sulphocyanide as low as ·001 per cent. already affect the growth of the plant, though it will germinate freely until the amount reaches about ·005 when the germination is not so vigorous and the young leaves are discoloured. The points at which germination and growth are actually prevented was not reached, but they are certainly very near ·02%. A further series will have to be sown in order to establish this point.

Experiments with sodium chlorate.

Six pots were prepared as in the previous instance with the following quantities of sodium chlorate:—

No. 69, ·001 per cent. $NaClO_3$
,, 70, ·002 ,, ,,
,, 71, ·003 ,, ,,
,, 72, ·004 ,, ,,
,, 73, ·005 ,, ,,
,, 74, ·006 ,, ,,

The results are as follows:—November 3rd, Nos. 69, 70, and 71 had germinated freely, No. 72 showed the effects of the salt, germination being slightly retarded. In No. 73 the foliage was discoloured, and in 74 the germination was very feeble and the young leaves discoloured and puny.

On November 21st the growth in No. 69 was fair but distinctly affected. In Nos. 70 and 71 the growth was more

strongly affected, the leaves in 71 having a bleached appearance. In 72, 73, and 74 the leaves were quite bleached and the plants dying.

It is thus seen that germination is unaffected till the amount of chlorate reaches ·004%, and that quantities above ·006% prevent germination. The growth of the plant is affected by ·001% and when the amount reaches ·004% the plant is killed.

Experiments with arsenious acid.

Six pots were filled and sown on October 24th, the following quantities of arsenious acid having been previously added:

No. 75,	·05	per cent.	As_2O_3
„ 76,	·10	„	„
„ 77,	·20	„	„
„ 78,	·30	„	„
„ 79,	·40	„	„
„ 80,	·50	„	„

On examining the pots on November 3rd germination was found to be unaffected except in the case of No. 80 in which the germination was somewhat retarded.

On November 21st the growth of No. 75 was very slightly affected, the effect increasing in the succeeding numbers. In No. 77 the growth was somewhat stunted and more markedly so in 78, 79 and 80, though the plants were small they looked fairly healthy.

Three other pots were sewn on November 28th:—

No. 81,	·60	per cent.	As_2O_3
„ 82,	·70	„	„
„ 83,	·80	„	„

On December 13th it was found that the germination had been affected in all cases. In No. 83, it was very strongly affected and the plants were very feeble. Above

this point germination would certainly be prevented. The plants in Nos. 81 and 82 were nearly dead by January 15th and in 83 quite dead.

The germination of maize is therefore not affected by the presence of arsenic in the soil up to ·4%, at ·5% however, germination is affected, and is prevented by quantities above ·8%; ·05% has an effect upon the growth of the plant and ·20% produces stunted plants, ·6 to ·7 being enough to prevent their growth.

These results are tabulated below:—

Effect upon germination and subsequent growth of Maize of different percentages of injurious substances in the soil.

	Germination affected.	Germination prevented.	Growth affected.	Growth prevented.
$NaCl$	·20	·50	·10	·25
Na_2CO_3	·20	·50	·10	·25
NH_4CNS	·005	above ·02	·001	above ·02
$NaClO_3$	·004	above ·006	·001	·004
As_2O_3	·50	above ·80	·05	·60

BIBLIOGRAPHY OF AUSTRALIAN LICHENS.

By E. Cheel.

[Communicated by J. H. Maiden, F.L.S.]

[Read before the Royal Society of N. S. Wales, Septemeer 2, 1903.]

The following is, as far as I can ascertain a complete list of publications on Australian Lichens issued previous to September 1903.—(E. Cheel).

[*Introductory Note.*—Mr. Cheel of the Botanic Gardens Staff is custodian of this group of plants in the National Herbarium, Sydney. A few years ago the Government purchased from the Rev. F. M. R. Wilson his collection of Lichens (chiefly Australian) comprising about 20,000 specimens. The number of species is not yet accurately determined. The herbarium has received large accessions of such plants from other sources.—J. H. Maiden, Government Botanist and Director of the Botanic Gardens, Sydney.]

New South Wales.

1. Brown, R.

   Flinders' Voyage to Terra Australis, Vol. II., pp. 593-4 (1814).

   A list of 58 lichens, common in Europe and Australia are given in this work.

2. Persoon, C. H.

   Freycinet's *Voyage autour du Monde (Botanique)*, pp. 187–215, Paris (1826).

   Four species are given from New Holland, two of which are from Port Jackson.

3. Crombie, J. M.

   Enumeration of Lichens (Australian) in Herbarium Robert Brown (British Museum)—*Journn. Linn. Soc.* (Bot.) Vol. XVII., pp. 390–401, (1880).

Seventy-three species are enumerated, twelve of which are new to science. Port Jackson and Grose River are mentioned in this State.

4. Woolls, W.

Contribution to the Flora of Australia, 163 – 173 (1867).

Fourteen species are mentioned by Woolls as having been collected, chiefly near Parramatta.

5. Krempelhuber, Dr. A.

Lichenes bearbeitet, *Reise der oesterreichischen Fregatte Novara* (Botanik) um die Erde in den Jahren 1857, 1858, 1859, Thiel I., pp. 107 – 129.

6. Krempelhuber, Dr. A.

Ein Neuer Beitrag zur Flechten-Flora Australiens.—*Verhandlungen Zoologisch-Botanischen Gesellschaft*, Wien, Jahrgang 1880, xxx., ii. part, pp. 329 – 342.

One hundred and twenty-two species are enumerated, several of which are described as new. Thirty-five are recorded for N.S.W., chiefly from Richmond and Clarence Rivers, and from New England district.

7. Knight, C.

Contribution to the Lichenographia of New South Wales.—*Trans. Linn. Soc.*, 2nd Series, Vol. II., p. 37, (1882).

Fifty-two species are enumerated, including forty new species, collected chiefly in the neighbourhood of Sydney.

8. Mueller, F., Baron von.

Fragmenta Phytographiæ Australiæ, XI., Supplement, pp. 70 – 74 and pp. 115 – 118 (1883).

9. Mueller, F., Baron von.

Victorian Naturalist, Vol, IV., pp. 88 – 95 (1887).

A list of Australian species are given by the Baron, several of which are from New South Wales.

10. Wilson, Rev. F. R. M.

Notes on Lichens in New South Wales—*Proc. Roy. Soc., Queensl.*, Vol. VI., pp. 85 - 88 (1889).

11. Wilson, Rev. F. R. M.

List of Lichens found in New South Wales—*Proc. Roy. Soc. Queensl.*, Vol. VI., pp. 89 - 93 (1889).

Two hundred and seventy-five species are enumerated by Wilson with the authorities of each for their occurrence in the field.

12. Zahlbruckner, Dr. A. von.

Lichenes Mooreani—*Annalen des k. k. Naturhistorischen Hofmuseums*, Wien, 1896, pp. 187 - 196 (Band XI., Heft. 2).

Several species are enumerated chiefly from Richmond River, Clarence River, National Park (near Sydney), and New England district.

13. Müller, Dr. Jean.

Analecta Australiensia—*Bulletin de l' Herbier Boissier*, Tome IV., No, 2, pp. 87 - 96, Fevrier 1896.

Two species are mentioned from Bellinger River, N.S.W., collected by Mr. J. H. Maiden.

14. Müller, Dr. Jean.

Lichenes Australienses—*Bulletin de l' Herbier Boissier*, Tome VI., No. 1, Janvier 1898.

15. Maiden, J. H.

Notes of a trip to Mount Seaview, Upper Hastings River—*Proc. Linn. Soc., N.S.W.*, Vol. XXIII., pp. 24-25.

Eight species are given, determined by F. R. M. Wilson.

16. Baker, R. T.

Contribution to a knowledge of the Flora of Australia, No. 2—*Proc. Linn. Soc. N.S.W.*, p. 446 (1899).

One species, namely *Parmelliella Baeurlenii*, (auct. ?) is mentioned.

17. Cheel, E.

Director's Reports on the Botanic Gardens, Sydney, presented to the Legislative Assembly, New South Wales, 1901-2 and 1902-3.

Several collections are mentioned from various parts of New South Wales and now deposited in the National Herbarium, Sydney.

18. Cheel, E.

An exhibit of 47 species or varieties of New South Wales Lichens—*Proc. Linn. Soc. N.S.W.*, 1903.

19. Watts, Rev. W. W.

A list of 27 Lichens, determined by Dr. Bouly de Lesdain of Dunkerque.—*Proc. Linn. Soc. N.S.W.*, 1903.

VICTORIA.

20. Hampe, Dr.

Plantæ Mullerianæ—*Linnæa* (Journal f. d. Botanik hrsg. v. Schlechtendal), Halle, Vol. xxv., pp. 709-712, 1853, and Vol. xxviii., p. 47, 1856.

21. Mueller, F., Baron von.

Report Botanic Garden, Melbourne, Legislative Council, pp. 18-19, (1854).

22. Mueller, F., Baron von.

Report Botanic Garden, Melbourne, Legislative Assembly, p. 13, (1858).

23. Krempelhuber, Dr. A. (See 6.)

24. Mueller, F., Baron von. (See 8.)

25. Mueller, F., Baron von. (See 9.)

26. Wilson, Rev. F. R. M.

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27. Wilson, Rev. F. R. M.

Descriptions of two New Lichens, and a list new to Victoria, —*Vict. Nat.*, Vol. v., pp. 29-31 (1888).

28. Wilson, Rev. F. R. M.
An Additional List of Lichens New to Victoria—*Vict. Nat.*, Vol vi., pp. 60-61 (1889).

29. Wilson, Rev. F. R. M.
A Description of 41 Victorian Lichens New to Science—*Vict. Nat.*, Vol. vi., pp. 61-69 (1889).

30. Wilson, Rev. F. R. M.
A Hunt for Lichens in East Gippsland—*Vic. Nat.*, Vol. vi., pp. 57-59 (1889).

31. Wilson, Rev. F. R. M.
Lichens from the Victorian Alps—*Vic. Nat.*, Vol. vi., pp. 178-180 (1890).

32. Wilson, Rev. F. R. M.
Notes on a Remarkable Lichen Growth in connection with a new species of *Sticta*, with description of both—*Proc. Roy. Soc. Queensl.*, Vol. vii., p. 8 (1889).

33. Wilson, Rev. F. R. M.
On Lichens collected in Victoria, Australia, (Communicated by Mr. Carruthers)—*Journ. Linn. Soc.*, (Botany) Vol. xxviii., p. 353 (1891).

34. Wilson, Rev. F. R. M.
The Lichens of Victoria, Part I.—*Proc. Roy. Soc. Vict.*, Vol. v., 2nd Series, pp. 141-177 (1892).

35. Shirley, J.
On Some Victorian Lichens—*Proc. Roy. Soc. Queensl.*, Vol. x., p. 54 (1894).

36. Müller, Dr. Jean.
Analecta Australiensia. (See 13).

37. Müller, Dr. Jean.
Lichenes Australiensis. (See 14.)

TASMANIA.

38. Labillardière, J. J.
Novæ Hollandiæ Plantarum, Vo. ii., p. 110 (1804).

39. Brown, R.

Flinders' Voyage to Terra Australis, Vol. II., pp. 593-4 (1814). (See 106.)

40. Sprengel, C.

Systema Vegetabilium, Vol. IV., part i., p. 271, 1827.

One species is mentioned, namely *Cladonia retipora*, Spreng. Syn. *Bæonyces retipora*, Labillardière. On p. 303, one species is mentioned from Nova Hollandia, but no province is given.

41. Taylor, Th.

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44. Knight, C.

Notes on Stictei in Kew Herbarium—*Journ. Linn. Soc.* (Bot.) Vol. XI., pp. 244-5 (1871).

45. Crombie, J. M. (See 3.)

46. Mueller, F., Baron von.

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48. Wilson, Rev. F. R. M.

The Climate of Eastern Tasmania as indicated by its Lichen Flora—*Proc. Roy. Soc. Tasm.*, p. 131 (1892).

49. Wilson, Rev. F. R. M.

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50. Shirley, J.
A List of the Known Lichens of Tasmania—*Proc. Roy. Soc. Tasm.*, p. 179 (1892).

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Lichenes Exotici—*Nouvelles Archives du Museum*, p. 105 (1892) Paris.

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Western Australia.

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On Thysanothecium a new genus of Lichen collected by J. Drummond in Swan River—*Hook. Lond. Journ., Bot.*, Vol. v., p. 257 (1846).

63. Taylor, Th.

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64. Fries, Elias (Christian Lehman).

Plantæ Preissianæ sive Enumeratio Plantarum, Vol. II, pp. 140 - 145 (1846-7).

65. Wilson, Rev. F. R. M.

Lichens from Western Australia-- *Vict. Nat.*, Vol. VI., p. 180 (1890).

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67. Knight, C.

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68. Knight, C.

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78. Shirley, J.
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82. Shirley, J.
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Several species of Australian Lichens are mentioned in this work showing the geographical distribution.

99. Leighton, Rev. W. A.
The Lichen Flora of Great Britain, Ireland, and the Channel Islands, Shrewsbury, 1879.

Leighton's work enumerates a number of Australian Lichens showing the geographical distribution.

100. Wilson, Rev. F. R. M.
Australian Lichenology—*Trans. Aust. Assoc. for the Advancement of Science*, Vol. ii., pp. 549 – 553 (1890).

This work gives a brief history of Australian Lichenology.

ON THE PROTECTION OF IRON AND OTHER METAL WORK.

By WILLIAM M. HAMLET, F.I.C., F.C.S., Government Analyst.

[*Read before the Royal Society of N. S. Wales, August 5, 1903.*]

THE practical applications of chemistry are being extended in every direction, invading even the domain of the engineer, the architect, and the builder, so that whosoever will come into line with modern requirement must first think somewhat of the nature and possibilities of his materials; for not only do the sciences of chemistry and physics underlie the origin, production, and manufacture of all kinds of material used in building construction, but there logically follows, with the advance of knowledge, the elucidation of the proper means and precautions which must be taken to ensure and maintain their stability and permanence, for at least a certain number of years.

Neglected and left to themselves, an engine, a ship, a house, a bridge, or a church will dissolve away molecule by molecule, atom by atom, linking themselves back again to the original forms which constitute the great majority. The tendency of matter is to conform to the laws of chemical equilibrium, in obedience to which, the finest and proudest structure is doomed to decay, and any of man's works, whether it be the most gorgeous of temples or the bravest machine that ever did battle with wind and weather on land or water, will pass away and disappear, under conditions that are said to be the ravages of time, but which is really the play of chemical energy: hence it comes to pass that in all our business undertakings we make due allowance for 'wear and tear.'

Instance a wooden girder or a pile: it is according to specification; satisfactory alike in form, nature and position, the timber is sound; it is able to stand the mechanical strain, and the stress and torsion expected of it. All this has been very carefully thought out in the calculations of the engineer, and remembered and provided for by the builder. Yet there are other hosts to be reckoned with, and these are:

I. Chemical (Electrical) influences.

II. Mechanical and meteoric influences; the erosion by sand, wind and rain, factory-chimney emanations, accelerated by expansion and contraction.

III. Biological influences and animal depredations.

I feel the subject widens under my treatment and that it involves the consideration of three clearly defined divisions of the subject: the general question of the structure of materials, their position in time and space, and thirdly their own special environment. To deal adequately with these, is more than I can hope for, but I think, we have in this threefold summary, all the factors concerned.

In regard to structure of materials, which is a vast subject and involves the consideration of the constitution of matter, I would mention that all kinds of matter whatsoever under suitable conditions from the most friable up to the hardest steel, carborundum or diamond, are capable of easy disintegration and solution in the chemist's crucible: so, conversely, he should know the conditions that determine the least amount of chemical action and decay, or in other words the conditions of permanence and protection. I pass by in review some of the materials used by early man: such as his flints, his diorites, granite and baked clay, the bronzes and the marble of the Egyptians, Greeks, and Romans, and come down to the iron of the twentieth century; chiefly for the reason that my attention has been

turned to iron and its congener steel, which are to-day so freely used in all structural works.

After the Bronze Age came that of the Iron, which must have covered a lengthy period of time, but with the discovery of the plentiful iron-ore deposits in the midlands of England, iron became greatly in demand for all structural purposes where its use could be economically adopted. The varieties of iron known to the engineer and builder were the wrought and cast, pig iron, white, grey, mottled, and malleable iron, and the metal associated with carbon, called steel. With the advent of the discoveries of Bessemer, Lowthian-Bell, Siemens-Martin, and Thomas, the practical ironmaster became interested in the composition and chemical analysis of the metal, the presence of a per cent. or rather the fraction of a per cent. of carbon making all the difference in the world in the properties of the metal. At the present time an additional method of ascertaining the strength and fitness of quality of these metals has been introduced, namely the observation of the actual structure of the metal itself. By structure I mean of course microscopic structure.

It has been found that the minute microscopic structure whereby the relative positions held by contiguous particles can be seen is of greater significance than elemental composition as ascertained by means of chemical analysis, for within the last few years great advances have been made by graphological methods, a mode of examination effected by means of etching the polished metal with an acid. The highly polished surface of the metal to be tested is etched either by electrolytic methods or by immersion into free acids, halogens, hydroxides, or peroxides. This method was first applied to the sections or slices of meteorites, and shews that perfect continuity, or perfect homogeneousness is never found in matter as we know it: that

matter is heterogeneous and discontinuous. In the case of the metals used in building construction, the apparent arrangement of the particles is either crystalline, fibrous, porous or granular as the case may be, and was usually obtained by the fracture, bending or torsion of the specimen. Although it was well known that toughness, hardness, brittleness, strength and elasticity were correlated to the visible grain or appearance of the fractured surfaces of the metal, yet the new method confirmed this and showed that strength and elasticity might be deduced from the minute microscopic structure of the sample to be tested, from which follows the discrimination between good and bad materials. So rapid has been the success of the examination that a journal has come into existence dealing with this branch of metal testing called the 'Metallographist.'

It is found in practice the best, *i.e.*, the most durable materials are those of even texture that is to say those of the most homogeneous structure. Strictly speaking even these are heterogeneous, but provided the structure be small, dense, and of uniform texture to the eye, or to an eye assisted by a magnifying power of seventy or eighty diameters, it may be provisionally or for all practical purposes be termed homogeneous. In many materials the process of what is known as annealing is nothing more than the application of heat with a view of breaking up what was once a coarse-grained crystalline structure and by slow cooling allow the molecule to set in uniform evenly placed positions.

Where different metals are present together, as in the case of an alloy, if the structure be irregular, coarse, and highly granular, then the metals having differing electric potentials under the action of an exciting liquid will set up short voltaic circuits and show corrosion: that is to say an electro-positive and an electro-negative metal in juxta-

position with the suitable excitant will, under ordinary conditions, lead to the corrosion and the final destruction of the more electro-negative element. But why, it will be asked, does one piece of Muntz metal for example, decay, while another will last for many years? The reason is based on the condition of the metal, its uniformity of texture, the eutectic condition of the alloy, a subject which I hope to discuss, in some researches I have on hand, at another time.

Suppose that in the construction of a wharf or jetty, you wish to protect a wooden pile from the action of the sea and its myriad forms of marine life. You may sheath it with iron, but the iron will very soon disappear; sheath it with sheet zinc and this will dissolve away and so leave the wood exposed and bare. Once more sheath it with yellow metal, and it may begin to corrode in a few months, or it may possibly last for many years sound and intact. This has been the experience of engineers in different parts of the world.

I pass over the interesting question of the adaptability of different metals suited to different purposes such as cast iron and gun metal used to withstand a static load or compression: wrought iron to resist dynamic stress and so forth, and I proceed to the universally known fact of the common rusting of iron, a phenomenon known to us from boyhood, and not only so, but known to the boyhood of the human race, as witness the many allusions to it in literature. The rusting of an iron nail, or a knife in a few hours is a common occurrence, but the serious magnitude of its possible damage is more apparent in the case of great structures, thus it has been recorded for example that no less than forty tons of iron rust were scraped off the Menai Bridge at one time when cleaning down preparatory to re-painting. Another instance, Sir Christopher Wren, in

building his famous London churches, clamped some of the stones together with iron clamps—a method which sounds both safe and simple, but in the course of years the iron had become so rusted and in the process of rusting had consequently so much expanded that the stones were loosened and burst asunder, so much so that only last year St. Bride's church steeple had to be pulled down and a new one is now in process of construction. Iron rust is simply iron plus oxygen and moisture, so that the rust must necessarily occupy more space than the iron from which it was formed, the difference being about double.

The chemical composition of rust is held to be that of the hydrated oxide of iron, the oxide represented by the formula Fe_2O_3 plus one or two molecules of water. The best authorities agree in admitting the presence of *two* water molecules corresponding to a formula of $F_2O_3(OH_2)_2$ or $Fe_2O_2(OH)_2$. The formation of rust is due to the action of oxygen and water on metallic iron, the action being greatly accelerated by the further action of carbonic acid gas, as these compounds are present everywhere both in the air and in water, it therefore comes to pass that iron will rust almost anywhere, but never without oxygen, even if immersed in water. I have some specimens of iron and steel which I hermetically sealed up in glass more than fifteen years ago, and I produce them to-night looking as bright and as clean as when I sealed them up. The water used was pure distilled water, all the oxygen being removed from it by prolonged boiling. I have before me some iron wire that has been packed in quicklime for about two years, and it is quite bright and clean, showing that if you exclude oxygen and carbon dioxide you may even, in the presence of water have no rust; or by excluding water and carbon dioxide even in the presence of oxygen no rusting occurs.

From numerous experiments made on this subject, I find that with dry iron there is no rusting: with wet iron and total absence of oxygen there is no rust; but with iron plus oxygen, plus water, plus carbonic acid there is rust, also with iron plus water and the peroxide of hydrogen, in the latter case the rusting occurs with or without carbonic acid.

The chemical mechanics of the process of rusting iron I take to be as follows:—an atom of iron in the presence of a molecule each of water and carbon dioxide results in the production of a molecule of ferrous carbonate with the liberation of a hydrogen molecule. Further, two molecules of the ferrous carbonate so formed, meeting with oxygen becomes ferric oxide, ferrous carbonate remaining; while two molecules of carbon dioxide are set free, and the reaction begins again *de novo* as long as there happens to be any more free iron to work upon.

Set out in symbols these two stages appear as follows:—

$$Fe + OH_2 + CO_2 = FeCO_3 + H_2 \text{ and}$$
$$2\,FeCO_3 + O = Fe_2O_3 + 2\,CO_2$$

The peroxide of iron, in the presence of water becomes hydrated, and so we finally have $Fe_2O_3\,(OH_2)_3$ which is iron rust.

To account for the rapid rusting of iron when in free access to unlimited action of water, it must be borne in mind that the air dissolved in natural waters is far richer in oxygen, the amount contained being about twice as great as the percentage of atmospheric oxygen, hence the rapid action when once iron has started to rust. The specific gravity of iron rust is only half that of metallic iron, the former being from 3·8 to 3·9, while iron is 7·8; this accounts for the great difference in the volume of the rust compared with the metal, while the energy of chemical action is quite enough to account for the displacement of heavy stonework when tied or clamped by bands of iron. Rusting causes

rapid surface deterioration, hence the economy of always keeping iron tools bright and shining, so that the brighter the iron the longer its life.

Before proceeding to the means of protecting ironwork from the ravages of meteoric changes it will be as well to consider the position of zinc, bronze, lead and copper. Zinc is now extensively used to protect iron from rusting, and when a thin film or layer of zinc is caused to adhere to iron it is said to be galvanised. Zinc is more electro-positive than iron, then why should it not decay sooner than iron? Galvanised iron admirably stands the weather, and, provided it is not subjected to the action of acid vapours, has a long life as a building material. Under normal conditions of both town and country life, when a sheet of galvanized iron is taken out of its original packing case all clean, glistening and bright, it becomes rapidly tarnished; but the tarnish is its own protection, forming a film of compact solid varnish that does not crack or peel off, and effectually protects the metal from further corrosion. The film of tarnish consists of zinc oxide which is insoluble. Under the influence of much carbonic acid a basic zinc carbonate sometimes forms, which is also insoluble. When a zinc building is erected very near the sea shore probably some of the halogen compounds of zinc are also present in minute quantities, these are actinic, and I think accounts for the decided blue appearance of galvanised iron structures built close on to the sea shore.

In the case of galvanized iron we have plain 'black' iron, then a coating of zinc to protect the iron, and after that comes the oxygen and lays on a coat of oxide which protects the zinc, a system of proceedings somewhat after the manner of 'this is the house that Jack built.'

In the case of bronze, the small amount of hydrogen sulphide present in the air is sufficient to produce a black

coating of sulphide of copper that protects the bronze for centuries ever afterwards.

Aluminium is also blackened, as witness the dome on one of our Government buildings in Sydney, and which you can see in the specimen of blackened aluminium which is here exhibited.

When lead is exposed to the air in the construction of a roof for example, it is very quickly covered with a film of oxide which is insoluble and has the good effect of protecting the metal against most ordinary conditions, but in the air of towns the film is changed to one of sulphide which is dense black, and this is why the church steeples of big towns and the lead roofs of public buildings are invariably black. In the country, however, the film may be white or yellowish-white, or with varying minute quantities of sulphide becoming a dingy grey, but as in the case of zinc, the compounds of lead so formed are insoluble in water and thus become preservatives.

Thus it will be seen that iron differs almost entirely from all other metals, for instead of forming an insoluble film or continuous coating, the rust cakes and peels and dissolves and in itself becomes a disintegrator, so that in a series of alternate stages the whole mass of metal is eaten through. Indeed so thorough has been this chemical change of oxidation of iron, that I have had cases of the whole of the solid iron being removed and the space filled by earthy matter and silica, a cast iron water pipe being so attacked that the substituted shell of the pipe could be ground to a powder by the pressure of the fingers. Under suitable conditions the near neighbourhood of electric light and traction mains will accelerate the decomposition of iron so profoundly as to lead to the utter destruction of underground water mains. The mere existence of conductors at high potential anywhere near unprotected water and gas mains is a matter

of the gravest importance to city councils and local authorities. The gravity of the question is accentuated, because under present ordinary conditions the mains are being slowly but surely eaten away by the rusting process constantly going on, caused by the flowing water, so that their renewal, at no distant date must eventually be faced.

The Sydney water supply as it comes from the catchment area consists of a soft water containing only three quarters of a pound of total solid dissolved matter in one thousand gallons (or eighty four parts in a million). But it is fully charged with air containing as it does 5·8 in a thousand of oxygen (5·8 cc. per litre). The carbonic acid taken up from the atmosphere amounts to about one part in a thousand. As soon as this water comes into contact with bare unprotected iron in any of the mains, chemical action proceeds rapidly, and a very perceptible amount of ferric oxide is carried about in suspension until at the furthermost outlets and in the dead ends of the reticulation of pipes considerable quantities of red sediment make itself visible, giving the water a rather repulsive appearance. It is due to the particles of red rust in suspension together with some vegetable matter which has become precipitated along with it owing to nuclear action of the masses of ferric oxide. In some systems of water supply where a soft water is collected, notably at Aberdeen in Scotland, the pipes have been quite choked up with rust and had to be cleared by mechanical means. The storage and transmission of water can be successfully accomplished without deterioration or injury to the water, but only when the interior of the pipes and the joints of the mains are properly coated and protected by means of some material that is so insoluble in water as to shield the iron from attack.

In the Sixth Report of the Rivers Commission the well known method of protection by means of Dr. Angus Smith's

composition is thus spoken of:—"Fortunately there is a simple method having the sanction of more than 20 years' experience by which this corrosion and its consequences can be prevented. The process which was invented by Dr. R. Angus Smith, F.R.S., Chief Inspector of Alkali Works, is conducted as follows:—The newly cast main or pipe is taken before oxidation has commenced, it is heated to about 500° Fahrenheit, and is then dipped perpendicularly into a bath containing a hot mixture of pitch, and heavy coal oil maintained at a temperature of 430° Fahrenheit. After a few minutes the pipe is raised and the surplus composition runs off. A black shining varnish remains on both inside and outside surfaces of the pipe, and even penetrates deeply into the pores of the iron. For the success of this process it is quite essential that the iron should be newly cast and hot."

"In his evidence before the Royal Commission of Water Supply (Ibid., page 114), Mr. Robert Rawlinson, C.B., M. Inst. C.E., the Chairman of the Rivers Pollution Commission appointed in 1865, says:—"I have never laid down cast-iron mains without this varnish. Cast-iron mains that have not been varnished, if they have laid five or six months on the ground, become oxidised both inside and outside, and pure water coming in contact with the commenced oxidation carries it on more rapidly. If you lay a varnished pipe six months on the surface it will not show one particle of rust, except where it has been scratched or abraided by rubbing the varnish off. In Whitehaven, soft water from Lake Ennerdale acted on cast-iron pipes, and in a very few years those of a small diameter (three inches) were all tuberculed, corroded, crusted up, and filled with oxidised matter, but nothing of that kind has ever occurred in any town that I have had to do with. At all events where we have had to cut pipes in Lancaster after eight or ten years

service we found no such blistering as that spoken of at Whitehaven."

By what means then can we secure the preservation or protection of iron against the inroads of the oxygen, water and carbon oxide molecules? The answer is that there are two fundamental principles on which a policy of protection can be based. Either to alloy with the iron some resistant elements, or coat the metal with something that is unaffected by the corroding elements. By the introduction of such elements as silicon, carbon and phosphorus the iron is made much more resistant or rust and corrosion by acids generally, but the iron is then of the variety known as 'cast iron,' and cast iron is precluded where toughness and tenacity is demanded, so that we are thrown back on some such coating as an oil, a varnish, a paint or the film of the magnetic oxide when the Barff-Bower process is used.

A paint is a substance, usually a coloured earth or artificial chemical product, called a pigment, ground in some suitable medium such as oil, water, etc., by which it can be spread on the surface to be painted. It is therefore a very simple substance consisting of pigment and vehicle: the one should be for the preservation and decoration of an object, the latter should be transparent, free from colour, and ought to dry readily. The best paints or pigments I know of, for the protection of ironwork are:—a varnish having carbon as its pigment in asphaltum, red lead, iron oxide, and the many varieties of carbon. Undoubtedly the best of media or vehicles is linseed oil which on exposure to the air becomes rancid with absorption of oxygen; this when spread over a surface in a thin layer dries to a tough skin which is insoluble in most liquids and even in ether, the union of the oil with the oxygen of the air forms a definite chemical oxidation product to which its repute and success is alone due. Turpentine is not to

be regarded as a medium at all, but rather as a diluent for linseed oil.

Another point deserving of attention is the question of the expansion of paint, which is very little thought of, and it should be borne in mind the difference in action in this respect between a varnish and a paint, the former shrinks while the latter expands. For a metal like iron that is used in positions where alternate expansion and contraction is frequent and inevitable, the most adherent and the most unchanging in regard to volume changes will obviously be the best. On the domestic hearth iron work has been protected for centuries by the application of the solid carbon popularly known as 'blacklead,' an instance of solid paint all pigment of body without either vehicle or medium, being simply rubbed on with a brush. But black lead, red lead, and white lead are very well in their place and under certain conditions there seems to be no universal covering composition that will be universally suitable for the protection of iron. Red lead I think, when it can be obtained free from adulteration, leads the record in practical value; and the engineer to the Water and Sewerage Board tells me that great success has followed the use of red lead and linseed oil.

One of the most striking instances of the corrosion of iron work that has come under my notice is that of the wearing away of the casing of one of our artèsian bores. The conditions so far as I know them are as follows:—the water is alkaline owing to the presence of carbonates and bicarbonates, the temperature of the water at the moment of flow is 95° F., and along with the water, sand and large pebbles are brought up to the surface by the impetuous uprising water. Common salt and bicarbonate of iron, with abundance of free carbonic acid is present. Among the gaseous constituents are hydrocarbons, methane, free

hydrogen and probably helium. The iron casing, or artesian tube, which forms the bore, was found to be so badly corroded that in places it was no thicker than tissue paper, and in many places was eaten away right through the metal, indeed it was as bad as if it had been subject to the action of one of the mineral acids. But the parts most corroded were localised in such a manner that it is probable the corrosion started at some particular point or focus in the metal, where some fragment of scoria, crystals of graphite or iron carbide, or some nucleus indicating a lack of homogeneity in the metal, and that therefore the casing was originally defective. This may have been so, and the faulty iron may be partly to blame, but I am of opinion that any iron subjected to a hot saline solution charged with carbonic acid gas with the abrading action of pebbles and sand combined, would sooner or later succumb to corrosion. Moreover, the presence of a nucleus of some foreign metal or compound, would set up electrolytic action: the artesian water would act as the exciting liquid and localised currents or polarisation would lead to the solution and decay of the casing. The presence of water charged with carbonic acid alone in contact with the bare iron at a temperature of 100° F. or over would dissolve the iron with liberation of hydrogen. Moody (Journ. Chem. Soc.) says that this action is strictly comparable to the action of sulphuric acid upon iron.

Petit in a paper published in the Comptes Rendus for 1896, p. 1278, says that a small quantity of carbonic acid is capable of doing much mischief to iron. When I visited the bore referred to some two years ago, I found considerable quantities of free carbonic acid and bicarbonate of iron. Wherever this water fell upon, or touched any object near the source or outflow, a peculiar phenomenon presented itself; a red rust or deposit of red oxide of iron made its

appearance, discolouring all the available objects round about. This was strikingly exhibited by the continual dropping of the water on an otherwise bright tinned dish which had received a coating of red oxide as though it had been painted with red oxide paint. On rubbing off, or dissolving off with a little mineral acid, the original clean tinned surface was again revealed just as good as new. The action may be represented by the following equation:

$$2\ FeH_2(CO_3)_2 + 3O = Fe_2O_3 + 2\ CO_2 + 2\ OH_2.$$

This corrosive action can doubtless be minimised by protecting the casing with some vitreous enamel or insoluble coating, or by the use of some new form of steel adapted for such special purposes, such as a steel containing tungsten, nickel, chrome; or a hard copper-aluminium alloy having sufficient resistant properties. But in the bore I allude to, the abrading effects of the sand, stones and gravel ejected, presents an unusual difficulty; if this could be overcome, then a hard resistant casing of some special manufacture would probably be the best means to preserve the casing from the solvent action of this water.

A COMPARISON OF THE PERIODS OF THE ELECTRICAL VIBRATIONS ASSOCIATED WITH SIMPLE CIRCUITS.

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With an Appendix by J. C. CLOSE, Deas-Thompson Scholar in Physics.

[*Read before the Royal Society of N. S. Wales, December 2, 1903.*]

INTRODUCTORY.

THE object of the present research has been to compare the periods of the electrical vibrations connected with narrow rectangular closed circuits with those of the oscillations associated with straight wires and with open and closed rings. The essential features of the experimental method are as follows:—A condenser is discharged in the neighbourhood of a narrow rectangular closed circuit; oscillatory currents are thus set up in the rectangle which in turn induce others in a third circuit of required shape. Observations of the amplitudes of the disturbances in the circuits are made with Rutherford's magnetic detectors, while the dimensions of the circuits are adjusted, step by step, until finally all three are in tune. The length of a circuit of any shape can thus be found which has the same period of electrical vibration as that of a given narrow rectangular closed circuit.

When the experiments were commenced, it was generally considered on theoretical grounds, that the wave length of the free oscillation connected with open resonators was equal to twice the length of the circuit,[1] and certain experi-

[1] Kirchhoff, Poggendorf's Annalen 121, 1864. Thomson, "Recent Researches," p. 340, 1893. Poincaré, "Les Oscillations Electriques," p. 237, 1894.

mental evidence had lately been published,[1] which apparently accorded with such a view. The well known experiments of Sarasin and De la Rive and others, however, make the wave length greater than twice the length of the resonator. It seemed essential therefore, to strengthen if possible, the experimental position, and with this object in view the present experiments were undertaken. Since their practical completion, theoretical support has been withdrawn from the results first mentioned, by the publication of Macdonald's Adams Prize Essay on Electric Waves, (Cambridge 1902) which has wholly changed the theoretical aspect. Macdonald's calculations so closely agree with the bulk of the experimental results that there can no longer be any doubt that the wave length of the free oscillation connected with open circuits is considerably greater than twice the length of the wire.

General Results.

Open circuits.—A. Slaby[2] has investigated, with a spark micrometer, the potential at various points of a straight wire when electrical vibrations take place along it. He finds a stationary wave with potential loops at the ends and a relative node at the middle. Such an experiment does not seem calculated to determine the actual wave length of the vibration connected with the wire, but apparently Dr. Slaby is satisfied from a consideration of the observations that the wave length of the oscillation is equal to twice the length of the wire. He has also theoretically discussed the problem and "the calculation gives a full confirmation of the experimental results." The experiments were made with wires from one to ten metres long.

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[1] Turpain—Jour de Phys. 10, p. 425, 1901. Slaby, Electrotech. Zeit. 9, p. 165, 1902.

[2] Slaby—Electrotech. Zeit. No. 9, p. 165, 1902.

Drude in the Annalen der Physik, 9, 2, p. 293, 1902, publishes an account of an elaborate research on the vibration period and self-induction of wire coils in connection with the construction of Tesla transformers. On p. 328 he gives the results of the investigation with coils with few windings and with single circles. Drude does not measure the period of the vibration connected with straight wires, but states that for a thin straight wire the half wave length is equal to the length of the wire. He refers to a calculation of Abraham,[1] which gives the half wave length 0·85% greater than the wire length, for a straight wire 0·25 cms. in diameter and 77 cms. long.

In the present experiments the comparison of the periods has been made in all cases between circuits constructed of copper wire 0·33 cms. in diameter and rectangles of thin brass wire 0·04 cms. thick, the rectangles being 30 cms. wide. It is found that the perimeters of the rectangles are greater than twice the length of straight wires which have the same period of electrical vibration, the ratio of the lengths varying from 2·45 for a rectangle 760 cms. in perimeter to 2·31 for one whose perimeter is 1,200 cms.

Approximately at least, the wave length of the electrical vibration associated with narrow rectangular closed circuits may be taken as equal to the perimeters of the rectangles. It appears then, from these experiments, that the wave length of the oscillation connected with a straight wire is much greater than twice the length of the wire, a result opposed to Slaby's conclusions and to Drude's statement.

For open circular resonators Sarasin and De la Rive[2] obtain results which are usually stated by saying that the wave length of the free electrical oscillation connected

[1] Abraham—Wied. Ann. LXVI., p. 471, 1898.

[2] Sarasin and De La Rive—Comptes Rendus CX., 1890; CXII., 1891; CXV., 1892.

with such circuits is equal to eight times the diameter of the circuits, or to 2·55 times the wire length. These results have been abundantly verified in a general sense, but it is doubtful if the statement is not too wide, as it takes no account of the diameter of the wire of which the resonator is made, nor of the shape or configuration of the ends of the circuit.

Turpain, from observations published quite recently, arrives at a different conclusion. He has investigated the problem of the vibration connected with circular resonators in an ingenious manner, by enclosing them in exhausted glass tubes, and judging of the electrical state of the wires by the luminosity produced in the rarefied gas. Turpain has published many accounts of his experiences, finally summarising his work in the Journal de Physique, Vol. x., p. 425, 1901. On pp. 435 *et seq.*, he describes experiments made with an open circular resonator and part of the inducing field enclosed in an exhausted vessel, and others where only the spark gap was surrounded with rarefied gas. In both cases it is stated that the resonator responds when one half the exciting wave length is equal to the length of the resonator. Turpain considers it experimentally established that "the length of the wave of the electric oscillation which excites a given wire formed resonator is equal (allowance being made for the micrometer perturbation) to double the length of the resonator." That a perturbation set up at the spark gap is not however responsible for any apparent discrepancy between theory and experiment was shown by the work of Strindberg[1] who confirmed Sarasin and De la Rive's results with a resonator in which no sparks occurred. If Turpain has interpreted his experiments aright his results must be considered at variance with the

[1] Strindberg—Comptus Rendus, CXXII., p. 1403, 1896.

great body of experimental evidence and with present theory.

Drude (*loc. cit.*, p. 330) gives the measures of the wave lengths of the vibrations connected with four open circles, three of them being supported by wooden cores and one being wholly surrounded by air. For the latter the half wave length was 259 cms. when the length of the wire was 243 cms., the ratio being 1·065. Drude concludes from this experiment that "the half natural wave length of a nearly closed thin wire circle is 6·5% greater than its length." This value I believe to be far too small.

With the circuits used, the present experiments give for the ratio of the perimeters of rectangles, 30 cms. in width, to the lengths of open circular circuits when both have the same period of vibration, values varying from 2·38 for a rectangle with a perimeter of 760 cms., to 2·28 for one whose perimeter is 1050 cms., the gaps in the circles being about 15 cms. long to avoid any appreciable capacity effect due to the proximity of the ends of the circuit.

Comparing this result with that given just above for straight wires, it is found that the electrical vibration connected with a wire bent into the form of a circle, with a considerable gap in its circumference, has a shorter period than that associated with a straight wire of the same length. The actual result obtained is that a copper wire 0·33 cms. in diameter, if bent into the form of a circular arc, with its ends separated by a distance of about 15 cms., requires to be 3·2% longer than a straight wire of the same gauge 310 cms. long, to give a radiation of the same wave length, and 3·4% longer than a straight wire 445 cms. long. This result is to be expected,[1] when the ends of the circular arc are not brought too closely together, as the inductance of

[1] See Thomson—"Recent Researches," § 385.

the wire is less in the circular form than when straight and the capacity is practically unaltered.

A further decrease of inductance without appreciable change of capacity can be made by bending the wire forming the open circle into the shape of a narrow rectangle with an open end. One would expect therefore, the period of vibration in such a circuit to be somewhat less than that in an open circle of the same perimeter. That the periods of electrical vibration connected with such circuits are at least nearly equal, when the perimeters are the same, is shown by a result obtained by Sarasin and De la Rive[1] in connection with their experiments with waves along wires. In these experiments it was found that the distance from the free ends of the wires to the first node was nearly equal to half the circumference of the resonator, and in such a case of parallel wires with free ends, the end section may be considered to correspond with an open rectangle. Macdonald[2] in giving the distance to the first node from the ends of the wire as 0·192 λ makes the ratio of wave length to perimeter of open rectangle 2·60, or the period of vibration in such a circuit longer than in the case of an open circle of the same perimeter. Bumstead[3] has investigated theoretically the reflection of electric waves at the free ends of a parallel wire system. If I understand his result aright, it means that the distance from the free end of the wire to the first node is always less than a quarter the wave length along the wires by half the distance between them. This cannot be generally true.

Kiebitz[4] has found the length of an open circle resonator when in tune with a straight rod oscillator. The rod being 250 cms. long, 248 cms. was finally taken as the resonance

[1] Sarasin and De la Rive—Comptes Rendus, cx, 1890.
[2] Macdonald—"Electric Waves," p. 121.
[3] Bumstead—Am. Journ. Sci., xiv., p. 359, 1902.
[4] Kiebitz—Ann. der Physik., v., 4, p. 872, 1901.

length for the open circle, a result slightly different to that given above, where the distance between the ends of the resonator was much greater than in Kiebitz's experiment.

Sarasin and De la Rive[1] as the result of their final measurements, give the wave length of the vibration connected with open resonators, made of stout wire 1 cm. in diameter, as 600 cms. for an open circle 234 cms. in circumference, and 400 cms. for one 156 cms. in circumference. This makes the wave length 2·56 times the length of the circuit. Macdonald, "Electric Waves," p. 111, in considering the question of stationary waves in open circuits, calculates the wave length for any resonator, and finds for the fundamental mode of vibration $\lambda_0 = 2{\cdot}53\ l$ where l is the length of the circuit; a value in wonderful agreement with Sarasin and De la Rive's conclusions. Apparently, according to theory the wave length is independent within wide limits of the diameter of the wire of which the resonator is made, and the ratio of wave length to length of circuit independent of the size of the circle.

By extrapolation (see Fig. 2) the present experiments give for a circle 200 cms. in circumference, the value 2·45 for the ratio of perimeter of rectangle to length of circuit. This is less than the ratio of wave length to circumference as given above by Sarasin and De la Rive for a similar size circle, and as calculated by Macdonald. In considering the difference, it is necessary to remember that extra capacity effects at the ends of the resonator may not have been altogether negligible in Sarasin and De la Rive's apparatus. On the other hand, the wave length of the vibration connected with narrow rectangular closed circuits, made of wire of finite thickness, may be a little longer than their perimeters. Again, the wave length may be

[1] Sarasin and De la Rive—Comptes Rendus, cxv., 1280, 1892.

affected by the diameter of the wire of which the resonators are made.

Closed rings.—Kiebitz[1] has shown how a filings coherer may be used to determine the existence of electrical resonance. In one set of experiments the coherer was placed across a gap in a circular resonator. The oscillator was a straight wire 77 cms. long. It is stated as the result of these trials, that with such a resonator there is the best response when its length is equal to the wave length of the radiation falling on it. This is asserting a little too much. The only statement justified by the experiments, on this point, is that the resonator gives the best response when its length is double that of the straight wire oscillator.

Kiebitz's resonator must be considered a completely closed ring, and his experiment proves the possibility of inducing oscillations in connection with such a circuit. The present experiments give a result not differing greatly from that just stated.

Turpain[2] from experiments with the resonator enclosed in an exhausted glass tube says:—"If one completely closes the gap, no current circulates in the closed circuit which the resonator presents. The electric density is zero at every point of the circuit at each instant." In view of Kiebitz's experiment this statement must be considered inaccurate.

The results of the present experiments on closed rings may be stated as follows:—Taking as a standard the period of the electrical vibration associated with a narrow rectangular closed circuit, where the longer side of the rectangle is parallel to the direction of propagation of the waves, an elliptical closed circuit of very small eccentricity, with its major axis parallel to the same direction, may be considered

[1] Kiebitz—Ann. der Physik., VI., 4, p. 741, 1901.
[2] Turpain—Journ. de Phys. X., p. 434, 1901.

to have the same period of electrical vibration if its perimeter is equal to that of the rectangle. If the eccentricity of the ellipse is increased, the perimeter has to be decreased to keep the period of vibration unaltered, until in the limit when the form becomes circular, the ratio of the perimeter of the rectangle to the circumference of the circle becomes 1·11 for a circle 800 cms. in circumference, the circle being made of copper wire 0·33 cms. in diameter and the rectangle, 30 cms. wide, of thin brass wire 0·04 cms. thick. If the form of the circuit is further altered so that the major axis of the ellipse becomes at right angles to the direction of propagation of the waves, the perimeter has to be further decreased to keep the period unchanged.

Pocklington[1] has calculated theoretically the period of the free electrical vibration associated with a closed circular ring and has arrived at the result that the wave length is rather less than the circumference of the circle. Kiebitz's experiment and the present investigation, give a value rather greater than the circumference. The problem of the electrical oscillations connected with closed circuits is discussed generally by Macdonald,[2] but calculations for special cases are not given.

Diameter of the wire forming the circuits.—St. John,[3] in experiments with waves along wires, for oscillations of the same period, obtains a 5% increase in the value of the wave length along parallel copper wires as the diameter of the wires changes from 0·04 to 0·12 cms. In St. John's investigation however, the problem is complicated by the presence of extra capacity at the ends of the circuit. No difference of period has been found in the present experiments between a rectangle made of thin brass wire 0·04

[1] Polkington—Proc. Camb. Phil. Soc., IX., p. 324, 1897.
[2] Macdonald—"Electric Waves," p. 62.
[3] St. John—Phil. Mag., 38, 1894.

cms. in diameter and one of copper wire 0·33 cms. thick. An open circle was compared with the rectangles in turn, and was in tune with each of them when its circumference was 380 cms., the perimeter of each rectangle being 886 cms. and the width 30 cms.

Permeability of the medium surrounding the circuits.—With the rapid alternations of current used in these experiments it is not to be expected that the permeability of the material of the circuit would have a considerable effect on the period of vibration (see St. John, *loc. cit.*). The permeability of the medium outside the wire on the other hand is of primary importance in this connection. This may be readily shown by surrounding the middle portion of a wire, where the current is concentrated, with fine, well insulated iron filings, and comparing the period of vibration with that of the wire in air. In the case tried, the central part of a straight copper wire 0·33 cms. in diameter, covered with paraffined paper, passed centrally through a glass tube 70 cms. long and 1 cm. internal diameter, the tube being filled with paraffined iron filings. The wire under these circumstances, when 345 cms. long, had the same period of electrical vibration as a copper wire of the same gauge wholly in air 370 cms. long.

Results.

In the following tables under the headings "perimeter of rectangle," and "length of straight (or curved) wire," the respective lengths of the two circuits, when the electrical oscillations connected with them are in unison, are placed in the same row, the fundamental mode of vibration only being investigated. The rectangles have been made with sides of thin brass wire 0·04 cms. in diameter, the ends being of copper wire 0·33 cms. thick. The other

circuits have been constructed wholly of copper wire 0·33 cms. in diameter. From the result of an experiment described above, I believe both circuits may be considered to have been formed of the copper wire. The rectangles were in all cases 30 cms. wide. Three methods have been used in the determinations. The results by the final one are considered of much greater weight than those by the earlier methods, and the observations have therefore, been divided in the tables.

Table I.—STRAIGHT WIRES.

Length of Straight Wire.		Perimeter of rectangle in tune with straight wire.	$\frac{\text{Perimeter of rectangle.}}{\text{Length of straight wire.}}$
Final method	Earlier methods.		
310		760	2·45
	355	860	2·42
370		886	2·40
	400	955	2·39
445		1050	2·33
	500	1165	2·33
520		1200	2·31

The relation connecting the above observations is shown graphically in Fig. 1.

Open circles.—The ends of the circles were bare and were separated by a distance of about 15 cms., so as to avoid any appreciable capacity effect due to their proximity. A result given by Mr. Close at the end of this paper, shows that in separating the ends of a bare ended resonator, 152 cms. in circumference, made of copper wire 0·33 cms. in diameter, practically no change is made in the period of vibration when the distance between them exceeds 8 cms. The actual length of the wire is given in the table under the heading "length of circular arc."

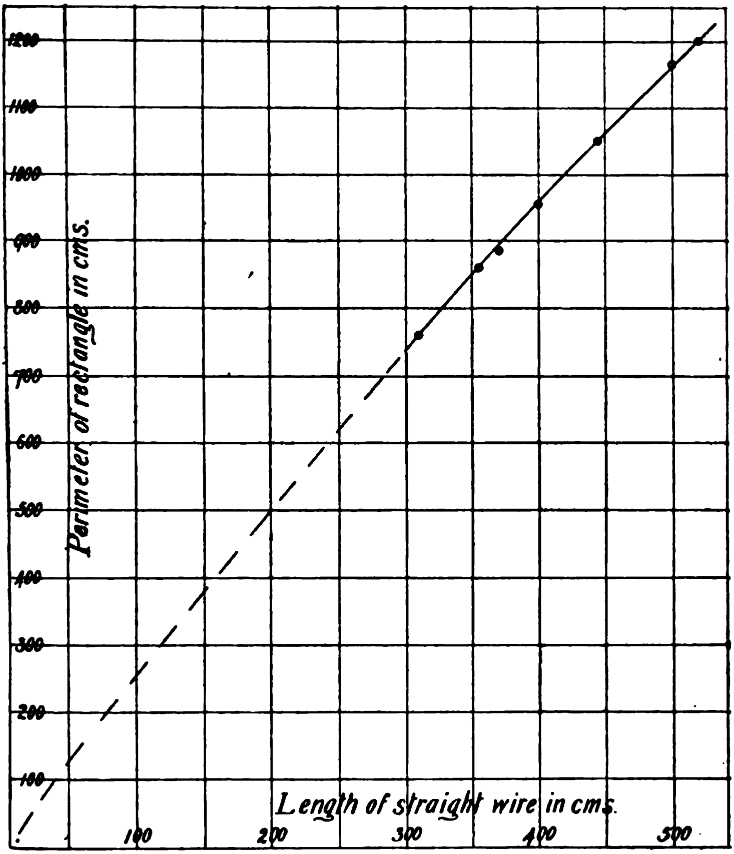

Fig. 1.

Table II.—OPEN CIRCLES.

Length of circular arc.		Perimeter of rectangle in tune with circular arc.	Perimeter of rectangle. / Length of circular arc.
Final method.	Earlier methods.		
320		760	2·38
380		886	2·33
	450	1030	2·30
460		1050	2·28

The relation connecting these values is shewn graphically in Fig. 2.

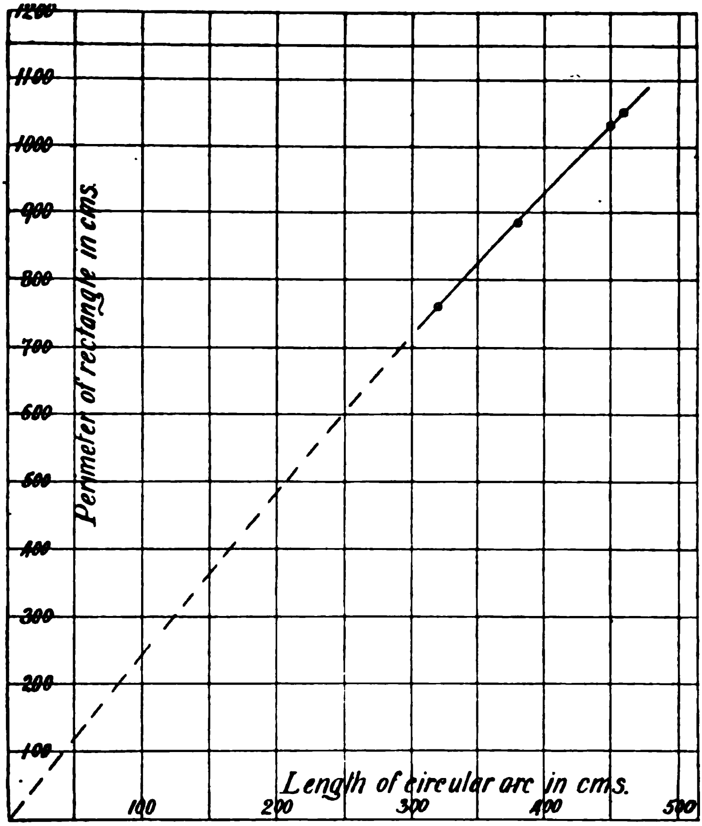

Fig. 2.

Closed circuits.—In the case of other than circular circuits no attempt was made to make the shape truly elliptical, and they must be considered merely as ovals approximating to the elliptical form. The perimeter and the ratio of the major and minor axes given in the table sufficiently indicate their shape. The ratio given is the length of the axis parallel to the direction of propagation of the waves along the circuit to the length of the axis perpendicular to this direction.

Table III.—CLOSED CIRCUITS.

Ratio of axes.	Perimeter of circuit.		Perimeter of rectangle in tune with circuit.	Perimeter of rectangle / Perimeter of circuit.
	Final method.	Earlier methods.		
6 78	850		886	1·04
2·37	830		886	1·07
2·33		750	815	1·09
1·00	670		760	1·13
1·00	800		886	1·11
1·00		900	990	1·10
C·69		750	872	1·16
0·56	760		886	1·17
0·53		750	880	1·17
0·28		750	900	1·20

The relation connecting the values obtained for closed circles is shown graphically in Fig. 3.

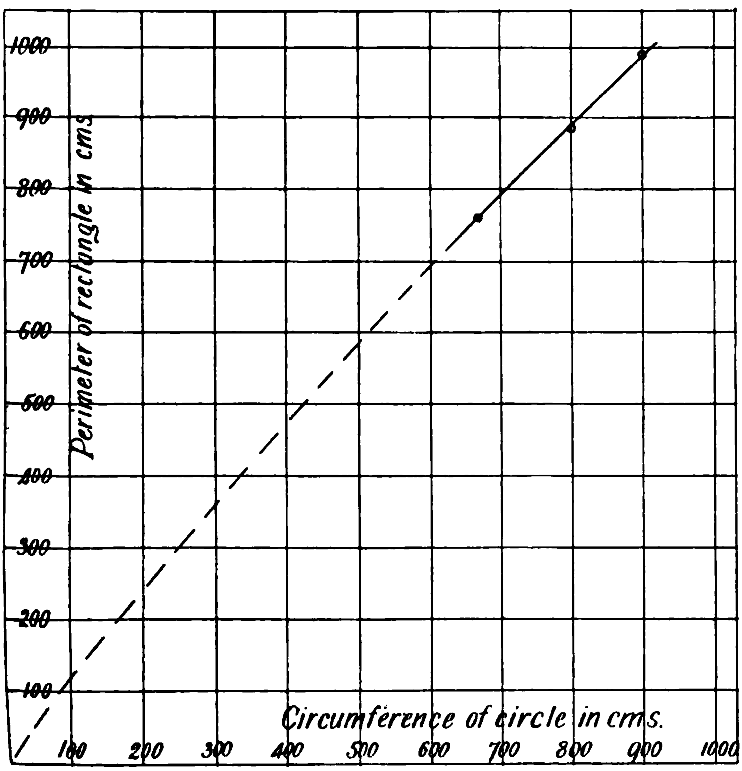

Fig. 3.

Experimental Details.

Three methods have been used in this investigation. In the first a condenser *C* with a discharge circuit *aa*, is arranged as indicated in Fig. 4, the diagram not being drawn to scale.

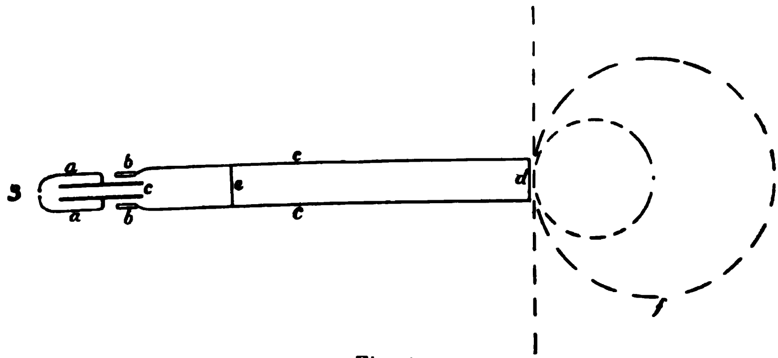

Fig. 4.

The condenser plates are attached to wooden stands, one of which can be moved by a screw, the two condenser plates always being strictly parallel. One of the discharge wires is cut and connection remade through a pool of mercury. This enables the condenser plates to be set at any distance from each other without disturbing the spark gap *s*. Two small hollow boxes *bb*, are placed close to the condenser plates. The boxes are provided with pegs which can be turned from the outside. To these pegs parallel wires are attached, the wires coming out through holes in the sides of the boxes. This arrangement of wires leading into hollow boxes was used by St. John,[1] and it enables the length of the wires to be conveniently altered without changing the capacity of the system near the condenser plates. The wires are bridged at their ends and at some other point as at *e*. At a distance of 1 cm. from the terminal bridge is placed a third circuit *f*, whose vibration

[1] St. John—Phil. Mag. 38, 1894.

period it is desired to compare with that of the rectangle formed by the parallel wires and the two bridges. In Fig. 4 the position of various third circuits used is shown in dotted lines.

A preliminary investigation has to be made to determine the relation between the length of the wires *cc*, and the distance between the condenser plates when the wire system and the condenser circuit are in tune. The procedure is as follows:—With a given length of the wires, observations are taken of the waves along them due to a discharge of the condenser, for different distances between the condenser plates. That position of the condenser plates is sought which is connected with the strongest vibration in the wire system with three nodes in its whole length. The investigation is made for various lengths of the wires, and curves are then drawn so that for any wire length the position of the nodes may be known, and the distance between the condenser plates found which makes the condenser circuit in tune with the wire system. The characteristics of the waves along the wires are determined by the use of the magnetic detector, invented and described by Rutherford.[1] The method is the same as that given by the author and Vonwiller in a paper on "Some Experiments on Electric Waves in short wire systems," published in the Phil. Mag. for June 1902.

To determine the length of a circuit of given shape which has the same period of electrical vibration as that of a rectangle, the circuit is placed behind the bridge *d*, as shown in Fig. 4, with a portion of it at which is situated a current loop, parallel to the bridge at a distance of about 1 cm. from it. In some experiments the terminal bridge has been removed and the ends of the parallel wires attached directly to the third circuit. The results have been the same in both

[1] Rutherford—Phil. Trans. CLXXXIX., (1897) p. 8.

instances. In the case of straight wires two small insulating tubes are placed symmetrically on the wire usually about 200 cms. apart. Each tube is encircled by a single loop of wire, the loops being attached by fine wires to mercury cups in a piece of hard rubber placed a little behind the middle of the straight wire, so that the ends of the solenoid of the detector may be joined to them. Readings with the detector are now taken on discharging the condenser, for various lengths of the parallel wires. At each adjustment of the length, the position of the bridge on the wires and the distance between the condenser plates are altered, by reference to the curves obtained in the preliminary investigation, so that the condenser circuit is always kept in tune with the parallel wire system. When the amplitude of the vibration in the straight wire is a maximum under these circumstances, as determined by the observations with the detector, the wave length of the vibration connected with the straight wire is considered to be the same as that associated with the rectangle formed by the parallel wires and the two bridges. Experiments with the other circuits have been made in a similar manner. A complete set of results was obtained by this method.

A second plan has been to set the condenser circuit and the parallel wire system in tune with each other and keeping this part of the apparatus fixed to alter the length of the third circuit by successive steps of 10 or 20 cms. From a plot of the observations of the disturbances in the third circuit, its length when it is in tune with the rectangle may be found. This method is more satisfactory than the former one, in that each successive step involves the alteration of only one of three circuits instead of two as in that case.

In repeating the experiments by this method the plots of the observations showed more decided maxima. When the

repetition was practically completed, owing to greater accordance among the observations due to the improvement in the character of the spark resulting from greater experience in the preparation of the spark knobs, two maxima close together, were noticed in the plot of the observations with one of the straight wires. As the position of the maxima could be altered by changing the condenser plate distance, the observation pointed to a want of success in tuning the condenser and rectangular circuits, an operation of considerable difficulty, and threw doubt on the accuracy of all the previous work.

It was decided therefore, after consideration, to do away with the hollow boxes attached to the rectangular circuit, which complicate the operation of tuning and simply place the narrow end of a fixed rectangle near the spark gap of the condenser circuit. The tuning of the condenser and rectangular circuits now involved only a change of the condenser plate distance. This operation was performed for three rectangles of different perimeters. It was found however, that a want of tune between the condenser and rectangular circuits could be better detected by observations of the disturbance in the third circuit than of that in the rectangle itself.

The following procedure was finally adopted as giving the most definite results:—For a given distance between the condenser plates observations are taken of the disturbances in the third circuit while altering its length by successive steps. This series of observations is repeated for various distances between the condenser plates. The plots of the observations show the relation between the disturbance in the third circuit and its length for various condenser plate distances. That distance between the condenser plates in connection, with which the plot shows the most definitely marked maximum, and in which the observations

are perfectly symmetrical round this point, is taken as the distance which makes the condenser circuit in tune with the rectangle.

This operation of tuning the circuits is a tedious one; it has involved in some cases the comparison of fifteen complete curves drawn from observations obtained as just described. Once the circuits are tuned. the series of observations necessary for a determination of the length of a third circuit when in tune with the rectangle, need only be repeated until the chance of a fortuitous accordance of the observations is eliminated.

Typical examples of the curves obtained are given in Fig. 5. The ordinates represent the difference of reading in cms. of the deflections caused by the detector before and after demagnetisation. They are proportional to the magnitude of the disturbances in the third circuit. Abscissæ represent the length of the third circuit, observations being usually taken for successive lengths differing by 20 cms. As the demagnetisation of the detector depends, *cæteris paribus*, on the length of the spark, such curves are only wholly comparable when they represent observation taken with the same spark gap.

In Fig. 5, curve 1 is a plot of observations taken in connection with one of the straight wires using the solenoidal detector. Curves 2, 3, 4, refer to the case of one of the open circles. They are the plots of series of observations, without alteration of spark gap, taken with condenser plate distances successively increased by 0·1 cm., the solenoidal detector being used. For tuning the condenser and rectangular circuits thirteen such curves were obtained, the series being extended and repeated three times to avoid any chance accordance of the observations. Curve 5 is a plot of observations with a closed ellipse using the longitudinal detector (see *infra*). In this case the observations

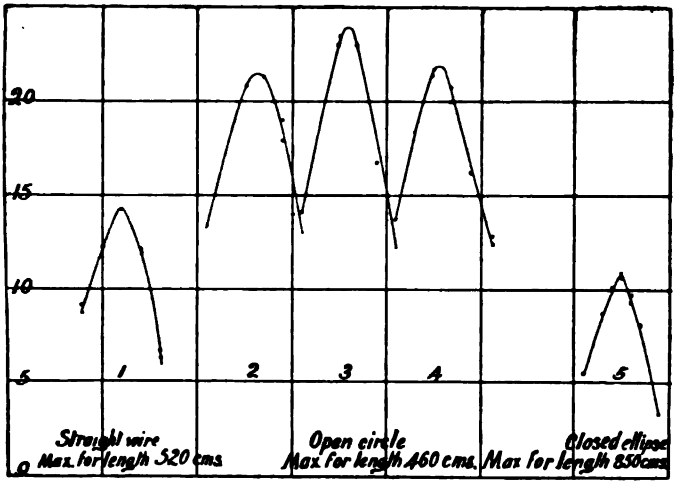

Fig. 5.

near the maximum were taken with ellipses differing in perimeter by 10 cms.

The maximum is much more definitely marked in the case of open circles than in circuits of other shapes and here a want of tune between the condenser and rectangular circuits seems to have less effect in altering the character of the curve of the observations than in other cases. It has been found a more difficult matter to get a series of accordant observations with closed circuits than with open ones.

The Sparks in the Condenser Circuit.—Practically the only difficulty in connection with the determination of numerical relationships in the case of Hertzian waves of small wave length lies with the spark which discharges the condenser. Many forms of detector are completely reliable. On the other hand the character of the sparks is so variable and the conditions which determine it, at present so obscure, that chance seems to enter largely into these investigations. Many spark knobs have to be tried in some cases before the observations become quite accordant. To obtain a

more uniform effect, a series of sparks may be taken for each observation, a method which has been used by many experimenters. As is well known, however, only a limited number of sparks can pass between the knobs before the character changes owing to the deterioration of the discharge surfaces. In the present case after trial, it was on the whole considered best to discharge the condenser once for each observation.

The condenser was charged from the secondary of a small induction coil. The primary circuit of the coil was closed and opened by two keys worked by a heavy pendulum, the interruption taking place very quickly. The circuit was opened in air, the gap being short circuited by the condenser of the coil. A variable resistance was inserted in the primary circuit and adjusted so that when the spark knobs were set, the difference of potential established on working the coil was just sufficient to break down the dielectric.

If the spark gap is watched through a lens, as in these experiments for each discharge, it is seen that successive sparks jump across the gap from different points of the knobs. Their character may be either round, long or irregular, either large or small, single or double, scarcely ever quite the same for two sparks together. The demagnetisation of the detector, has been found to so greatly depend on the path of the spark and on its character that it was useless to retain any observations except in those cases where the sparks took place across the centre of the gap and where the character was as far as could be judged the same for all. Hundreds of observations have been rejected on account of irregularity of the spark. On the other hand, hundreds of discharges where the sparks looked perfect, have given results utterly non accordant.

For the earlier of these experiments the sparks took place between aluminium spheres 1 cm. in diameter. The spheres

were constantly repolished and were immersed in a large bath of paraffin kept well stirred. A considerable improvement resulted on replacing the aluminium spheres by small spheres of platinum made by rounding the ends of platinum wires 0·13 cms. in diameter in the oxyhydrogen flame. With a flame not too hot, and with patience, little hemispheres can be finally obtained on the ends of these wires, whose surface and figure seem to leave nothing to be desired. About 30 sparks can in general be taken from such ends, though many more in some cases, before they require to be refused. In some few instances series of observations have been obtained accordant among themselves, but differing from another series with the conditions unaltered. This has been due no doubt to the apparently chance nature of the character of the spark. No result has been retained which has not been fully confirmed by repetition.

The Detectors.—For the majority of the observations and particularly for the final ones, Rutherford's solenoidal detector bas been used. In the later experiments with straight wires, where the length of the wire is altered, keeping the wire attached to the detector loops at a fixed distance apart on the straight wire as described above, tends to increase the reading for shorter lengths. Such action however, has been found not to affect the result. In the experiments with open circles the loops of the detector wires were always at the ends of the circular wire and in those with closed circuits always at the ends of a diameter at right angles to the long side of the rectangular circuit.

To show that the length of the detector wires does not influence the result of an experiment, the following trials were made with a straight wire:—(1) the wires to the detector each 100 cms. long once looped round an insulating

tube on the straight wire; (2) wires each 40 cms. long soldered to the straight wire; (3) wires 25 cms. long soldered to the straight wire; (4) wires 10 cms. long soldered to the straight wire. In each case the observations gave the same result, the straight wire 400 cms. long being in tune with a rectangle 955 cms. in perimeter.

Further an exhaustive comparison has been made between the results given by the solenoidal detector and those obtained with Rutherford's longitudinal detector. The latter was made of a piece of pianoforte steel wire 5·5 cms. long, which had been dissolved in acid until its diameter was 0·014 cms. The ends of the steel wire were soldered to two pieces of copper wire, each 1 cm. long and 0·33 cms. in diameter. The wire was then firmly fixed by means of the copper ends in a glass tube, the copper pieces projecting a few millimetres beyond the ends of the tube. In an experiment the detector, after being magnetised to saturation, replaced a similar length cut from the middle portion of the circuit under investigation. Connection was made by amalgamating the copper ends which were in contact, excess of mercury always being present. The magnitude of the disturbance in the third circuit is estimated by its demagnetising effect on the steel wire, the detector being placed after magnetisation and demagnetisation in a geometrical clamp with one of its poles close to the magnet of a magnetometer.

The results obtained with the longitudinal detector in no less than 16 cases are identical with those found with the solenoidal one, showing that the demagnetisations of the core of the latter are not affected in the present instance by any vibration peculiar to the detector circuit. This point has also been considered by Chant.[1] The circuits examined have been made of copper wire 0·33 cms. in

[1] Chant—Am. Journ. Sci., xv., p. 54, 1903.

diameter; the increase of inductance due to replacing 5 cms. in the central part of the circuit by the fine steel wire seems to have been negligible.

It has been found in this research more difficult to work with the longitudinal detector than with the solenoidal one. The former requires more delicate handling and a more sensitive magnetic arrangement for detecting changes of magnetisations.

The experiments have been carried out in a room 10 metres long by 6 metres wide, bare with the exception of gas and water pipes around the walls.

The Physical Laboratory,
The University of Sydney,
November 25th, 1903.

APPENDIX.

THE EFFECT OF CAPACITY AT THE ENDS OF A CIRCULAR RESONATOR.

By J. C. CLOSE, Deas-Thomson Scholar in Physics.

WITH a similar apparatus to that described in the preceding paper, but of smaller dimensions, the vibrations connected with open circular resonators were compared with those of a narrow rectangular closed circuit. The resonators were made of copper wire 0·33 cms. in diameter, and the wire was in all cases 152 cms. long. The rectangle was made of thin brass wire 0·04 cms. thick, the width of the rectangle being 31 cms. The experiments were made by the first method described above, in which the length of the resonator is kept constant, the length of the parallel wires being altered by winding the wire into the little boxes. In an experiment, the length of the parallel wires was altered by steps of 5 or 10 cms. and readings taken of the disturbance in the resonator on discharging the condenser with a Rutherford solenoidal detector. The observations

with the detector were plotted against lengths of rectangular circuit and a curve drawn freely through the points obtained. The crest of the curve has been taken as marking the length of the rectangular circuit when in tune with the open circle.

The sparks which discharged the condenser took place between aluminium spheres immersed in paraffin oil. In spite of the fact that the discharge surfaces were kept well polished the sparks were not uniform in character; this accounts for the variations in the readings. At least two sets of observations were taken in determining the position of each crest. A specimen curve is given in Fig. 6.

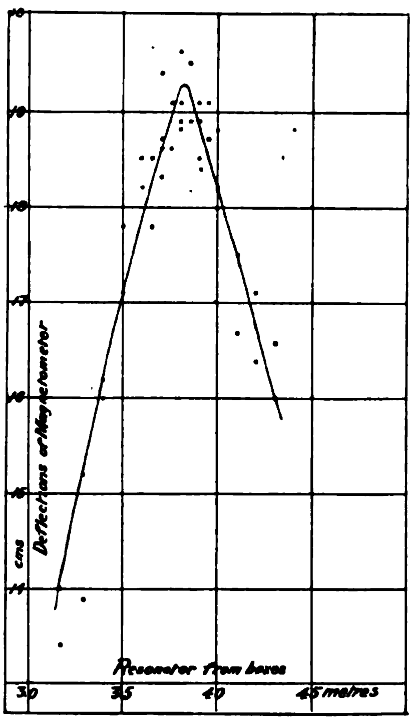

Fig. 6.

Observations were first taken with a resonator with bare ends, the distance between them being varied from 0·05 to 4·7 cms. Two other resonators were tried, one with spheres 1·7 cms. in diameter on its ends, and the other with spheres 2·2 cms. in diameter, the length of the wire connecting the two spheres being 152 cms. in both cases. The following is a table of the results obtained, the distance between the knobs being the length of the gap in the circuit :—

Table IV.

Wire length.	Diameter of spheres at ends of wire.	Distance between surfaces of spheres.	Perimeter of rectangle in tune with resonator.
152 cms.	0·0	0·05 cms.	404 cms.
,, ,,	,,	3·05 ,,	387 ,,
,, ,,	,,	4·70 ,,	387 ,,
152 cms.	1·70 cms.	0·20 ,,	425 cms.
,, ,,	,, ,,	0·78 ,,	420 ,,
,, ,,	,, ,,	9·10 ,,	396 ,,
152 cms.	2·20 cms.	0·20 ,,	428 cms.
,, ,,	,, ,,	0·78 ,,	423 ,,
,, ,,	,, ,,	3·95 ,,	404 ,,

The relations between the values given in the above table are shown graphically in Fig. 7.

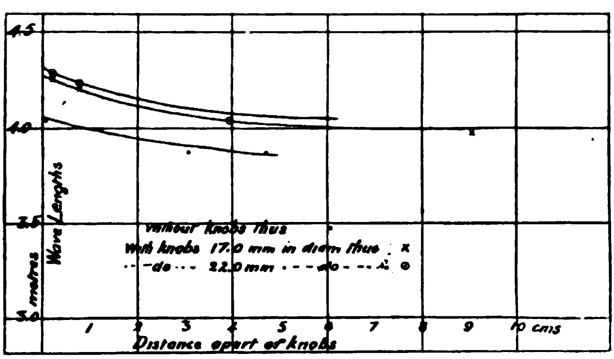

Fig. 7.

The curves show the effect of extra capacity at the ends of the resonator in increasing the period of the free vibration. The effect of bringing the ends of the resonator closer together is to increase the end capacity, and hence the period. In separating the ends practically no change is made in the period of the free vibration when the distance between the ends exceeds 8 cms. Several attempts were made to determine the period of the free vibration of the resonator with bare ends close enough for a spark to pass between them, but they were unsuccessful.

The Physical Laboratory,
The University of Sydney,
December 8th, 1902.

A CONTRIBUTION TO THE STUDY OF THE DIELECTRIC CONSTANT OF WATER AT LOW TEMPERATURES.

By O. U. VONWILLER, B.Sc., Demonstrator in Physics in the University of Sydney.

[*Read before the Royal Society of N. S. Wales, December 2, 1903.*]

THE experiments described in the following paper were carried out with the object of investigating the variation of the dielectric constant of water with temperature in the neighbourhood of 4° C. C. B. Thwing[1] carried out some experiments which apparently showed the existence of a critical point at 4° C., the dielectric constant rising to a maximum value at that point, and then decreasing as the temperature rose further. Drude,[2] Palmer,[3] and other observers have failed to obtain evidence of this effect.

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[1] C. B. Thwing—Phys. Rev., II., p. 35.
[2] P. Drude—Wied. Ann., LIX., p. 17. [3] A. de F. Palmer—Phys. Rev. VI., p. 267.

The author's experiments were carried out with electrical oscillations having a frequency of about 25 millions, produced in a Lecher wire system by the oscillatory discharge of a condenser. The arrangement of the apparatus is shown in Fig. 1. *A* is a condenser, consisting of two parallel cir-

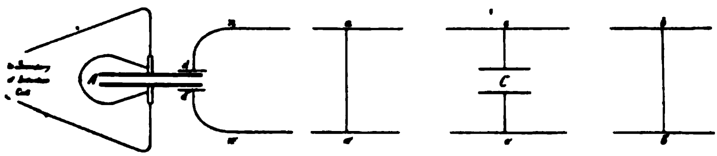

Fig. 1.

cular brass plates, 30 cms. in diameter, connected to the ends of the secondary of an induction coil. This condenser is discharged by means of a spark between two aluminium knobs immersed in kerosene, and joined to the condenser plates by brass rods 3 millimetres thick and 30 cms. long, bent into an approximately circular form. Two circular brass plates $d\,d'$ 8·8 cms. in diameter are held 8 millimetres from the plates of *A*, and attached to them are brass wires $d\,b$, $d'b'$ 0·36 millimetres in diameter and 30 cms. apart, except the portions $d\,n$, $d'n'$, each of length 27 cms., where the wires curve in. Two bridges of copper wire, $a\,a'$ and $b\,b'$ are placed across these brass wires. The circuit $daa'd'$ is called the primary, and $ab\,b'a'$ the secondary.

Across the wires is placed a light wooden slider, the wires passing through small glass tubes attached to it; round each of these tubes is a single loop of wire which leads to the terminal of a Rutherford detector, the deflections produced by which on a magnetometer, are used in determining the character of the oscillations set up in the wires. The details of the detector and the method of using it are similar to those used by Professor Pollock and the author in their experiments on Electric Waves in Short Wire Systems.[1] With the bridge aa' at a distance of 170

[1] Pollock and Vonwiller—Phil. Mag., June 1902.

cms. from nn', the wooden slider carrying the detector being 5 cms. from nn', the capacity of A was altered by varying the distance between the plates until the primary was in resonance with the condenser vibration; the deflection produced by the detector being a maximum when this is the case. The effective length of the primary is now $\lambda/2$, where λ is the wave length of the condenser radiation.

By altering the position of the bridge bb' the secondary can be brought into resonance with the primary, this being the case when its effective length is λ, the correct position being determined by keeping the slider midway between the two bridges, *i.e.* at a loop of the wave, and altering the length of the circuit until a maximum deflection is obtained.

In these experiments a condenser C was placed across the wires at some place cc'. The effect of this capacity is equivalent to an addition to the length of the wires, the wave length of free vibrations in the circuit $abb'a'$ being given by λ in the equation—

$$\cot \frac{2\pi a}{\lambda} + \cot \frac{2\pi b}{\lambda} = \frac{2\pi}{\lambda} \frac{C}{s}$$

as is shown by W. B. Morton,[1] a and b being the distances from the middle points of the bridges aa' and bb' respectively to the condenser, C being the capacity of the condenser and s the capacity per unit length of the two parallel wires. If the secondary is in resonance with the primary, a change in the capacity of C will throw it out of resonance and the deflections produced by the detector will be smaller.

An investigation of Morton's formula shows that a given percentage change of capacity produces the greatest proportionate change in the effective length of the circuit when $a = b = \lambda/8$, the effect of the capacity being thus equivalent to an addition of $\lambda/2$ to the length of the circuit. It has always been observed however, that when the

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[1] W. B. Morton—Phil. Mag., May 1897.

primary and secondary are in resonance, a comparatively great change in the effective length of the secondary is necessary to produce an appreciable change in the deflection, but when the two circuits are put further out of resonance the deflections varied by a considerably greater amount for a given alteration of length of secondary.

In order to determine the conditions under which the greatest change in deflection could be obtained for a given percentage change in the capacity of C, the detector being placed in the secondary circuit, a series of trials were made with an air condenser, consisting of two circular zinc plates, 30 cms. in diameter, the capacity of which was varied by altering the distance between the plates. In these trials a and b were given various values and as a result it was found that the highest degree of sensitiveness was obtained when $a=b=\lambda/8$ approximately, the capacity being considerably too great to give good resonance.

With this arrangement the slider was placed close to the condenser, but of course was practically equivalent to being about half way between the bridge and the middle of the circuit, *i.e.*, half way between a node and a loop of the wave, and so the deflections obtained were really considerably smaller than if it could have been placed at the loop.

A condenser with water as its dielectric was now attached to the wires in the position where the best results were obtained with the air condenser. Here $a = b = 300$ cms. and the slider was between a and c, and distant 5 cms. from the latter point. This condenser consisted of two wires similar to the main wires, and each 25 cms. in length. These wires first ran horizontally towards one another and then were bent vertically downwards, at a distance varying in different experiments from 9 to 11 cms. apart, dipping into water placed in a large glass vessel.

With the water at the temperature of the room the depth to which the wires were immersed was varied by increasing or decreasing the amount of water in the vessel, and so varying the capacity. The depth was altered until the deflection obtained was about the same as that obtained with the air condenser when its capacity was such that the arrangement was in its most sensitive state. The water was then removed and ice cold water poured into the vessel to the same level, and readings were taken at frequent intervals as the temperature rose, the temperature of the water being observed on two mercury thermometers, and the water being continually stirred except for a short time before sparking, when it was allowed to settle down.

As the temperature rose, the change of capacity was indicated by a change in deflection. Between 0° and 15° there was on the whole, a decided increase in deflection, showing a decrease in capacity, but owing to irregularities in sparking it was impossible to say definitely whether the deflection at 4° C. was higher or lower than at 0° C., the variation in successive sparks being so great as to mask the change between these points.

On several occasions there appeared to be an indication of a minimum deflection in the neighbourhood of 4° C., but on other trials, apparently equally reliable, this result was not obtained. In any case the variation of capacity necessary to produce the apparent change would have been very small,—much smaller than that obtained by Thwing, which would have produced an unmistakeable change.

Single sparks only were taken, the deflections obtained thus being more regular on the whole than those in which a series of sparks were taken for each observation. In order to obviate this variation of deflection due to the irregular sparking, another slider and detector were placed near the end of the primary circuit, and the deflections

produced by this detector on a second magnetometer were observed. These deflections should have been constant, but of course varied considerably with the spark. With the secondary circuit unchanged, when a series of readings were taken, although the deflections produced by either detector varied considerably, the ratio of the two deflections was found to vary to a considerably less extent.

In the following table is given a set of four readings of deflections of primary and secondary detectors and the ratio of the two, no change being made during the four readings:—

δp	δs	$1000\ \delta s/\delta p$
31·5	28·7	911
37·1	33·5	903
34·4	31·8	924
32·5	29·6	911

δp being the deflection produced by the detector in the primary circuit, and δs the deflection produced by the detector in the secondary.

Accordingly in subsequent experiments, the deflections produced by detectors in both primary and secondary were taken after each spark, and the variation of the ratio of the two observed. These experiments all showed an undoubted continuous fall in capacity as the temperature rose, there being no critical point at 4° C.

In order to ascertain the extent of the change of capacity a condenser consisting of two circular brass plates, 30·2 cms. in diameter and ·755 cms. thick, which could be moved apart in a direction perpendicular to their planes, was substituted for the water condenser, and observations were taken with the plates at different distances apart. The capacities at these distances were calculated by Kirchhoff's formula: (Abhandl. p. 112.)

$$C = \frac{r^2}{4a} + \frac{r}{4\pi a}\left[-a + a \log \frac{16\pi r\,(a+d)}{a^2} + d \log \frac{a+d}{d}\right]$$

when C is the capacity of the condenser, r the radius of the plates, d their thickness, and a the distance between them. The resulting curve between capacities and the ratio 1000 $\delta s/\delta p$ is shown in Fig. 2.

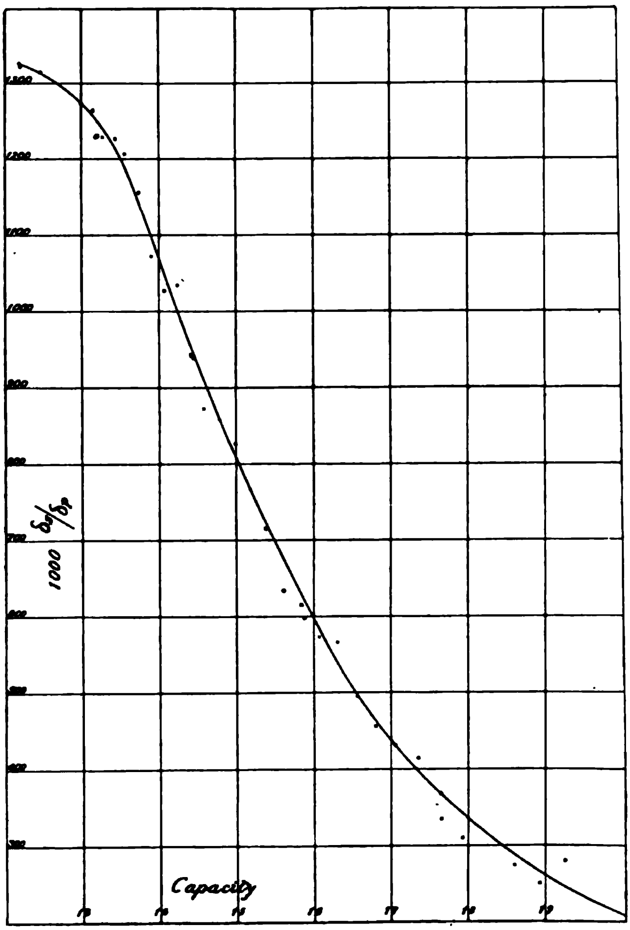

Fig. 2.

This curve shows how the sensitiveness for a given change of capacity decreases as we approach the position of resonance.

Figures 3 to 6 were now drawn, in which the abscissæ represent temperatures and the ordinates the capacity of the water condenser, the capacities being obtained from the curve in Fig. 2 for the value of 1000 $\delta s/\delta p$ obtained at the various temperatures.

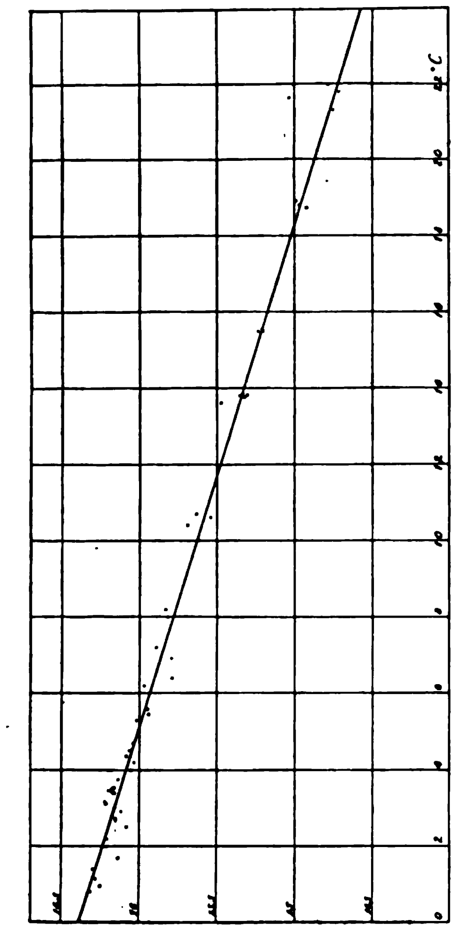

Fig. 3.

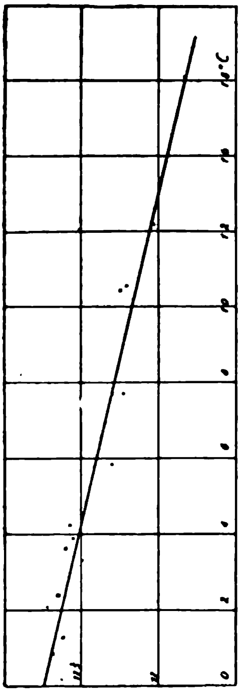

Fig. 5.

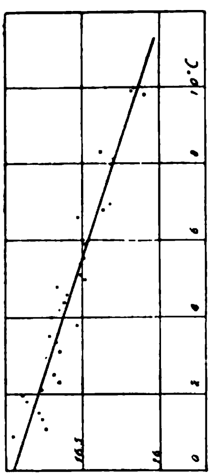

Fig. 4.

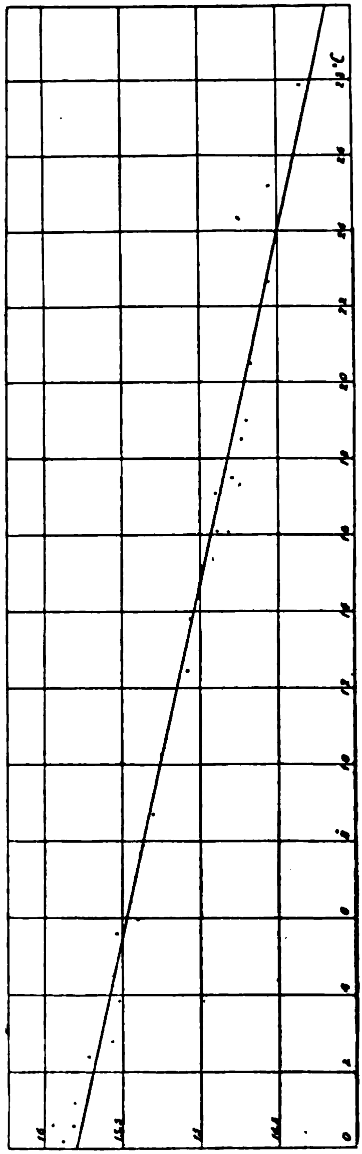

Fig. 6.

In all these curves there is to be noticed a decided fall in capacity as the temperature rose, and the curve is practically a straight line.

The change of capacity for 1° rise in temperature, expressed as a percentage of the capacity at 0° C. obtained from these different curves is, in Fig. 3, 0·464 ; Fig. 4, 0·478; Fig. 5, 0·287 ; Fig. 6, 0·344.

The dielectric of the condenser consisted partly of water and partly of air, the wires being out of the water for a considerable part of their length, and as the variation affected only the water, the total percentage change of capacity is less than the actual change in the dielectric constant of the water.

In the first two trials recorded above, the water was placed in a large glass vessel 25 cms. square, and the depth of water in it was about 15 cms., but in the other two, the water was placed in a beaker 15 cms. in diameter, and the depth of water was about 15 cms., so in this case the air would have a greater relative share in the whole effect, and so the observed variation is less than in the former trials where the variation in capacity is probably very nearly equal to the variation of the dielectric constant of water. In all four trials the wires were immersed to a depth of from 5 to 6 cms. and were from 9 to 11 cms. apart.

The assumption has been made, that, when the same deflection is obtained with the water and air condensers, the capacities are the same. By removing water from the vessel and so decreasing the capacity, we can come into a position of resonance, and it was found that on doing so the maximum deflections obtained were practically the same as the greatest deflections obtained with the air condenser, and so the conductivity of the water has no appreciable effect, and the above assumption is probably

permissible. Distilled water was used and its specific conductivity was measured and found to be $3{\cdot}7\times10^{-6}$ at 18·8° C.

These results show no indication whatever of the effect observed by Thwing at 4° C. With the possible exception of Fig. 5, all the curves are definitely lower at 4° than at 0°. According to Thwing, the dielectric constant at 0° is 79·46, and at 4° 85·20, *i.e.*, it increases by 7·2%; now, in Fig. 3, the capacity at 0° was 16·39, and if it were to increase by 7·2% it would be 17·57 at 4°; an inspection of the curve shows that any change of that order could not fail to be detected.

In conclusion, I desire to express my best thanks to Professor Pollock for many valuable suggestions, and for his continued encouragement during the work.

THE NARRABURRA METEORITE.

By A. LIVERSIDGE, LL.D., F.R.S., Hon. F.R.S.E.,
Professor of Chemistry in the University of Sydney.

[With Plates XI.-XXII.]

[*Read before the Royal Society of N. S. Wales, September 2, 1903.*]

Discovery.—Mr. Russell, C.M.G., Government Astronomer for New South Wales, states[1] that this siderite was found in 1885 by Mr. O'Brien; it was lying on a hard and stony surface at a place on Yeo Yeo or Narraburra Creek, about twelve miles east of Temora, in Lat. 34° 10′ S. and 147° 43′ E. Mr. O'Brien gave the meteorite to Mr. Patrick Harold of Mount Hope near Cootamundra, who presented it to Mr. Russell, on March 30th, 1890.

[1] Journ. Roy. Soc. N.S.W., June 4th, 1900.

External Structure.—Mr. Russell mentions that the meteorite is much rusted, and is very irregular in outline, and contains large rounded holes. The usual coating of fused oxides is not present, it has probably been removed by long exposure of the meteorite to the weather, and its surface is now merely rusty. He found its weight to be 70 lbs. 14 ozs., and its sp. gr. 7·57. The general appearance of the meteorite is shown by *Plates 11* and *12*, and the internal structure by *Plates 13* to *22*.

The surface is deeply pitted, the largest of the pits are numbered and their principal dimensions given on the *Plates 11* and *12*; from the depth and character of some of them they do not appear to have been formed by pieces splitting off, and it is probable that most of them have been formed by the melting of the fusible troilite and its fluxing action upon the adjacent metal; some may also have been increased by subsequent weathering.

Sections.—On cutting the meteorite, with a power-driven hack saw, it was found to be very hard and especially in places near the troilite nodules and the dark bordered elongated crystals (see *Plates 12* and *14*). A record was kept of the loss in weight of the saws used, the weight of the sawdust produced was 1852·36 gms., and the loss in weight of the saws employed was 2·83 gms., so that the amount of steel from the saws, mixed with the meteorite sawdust was only about 0·15% In spite of the introduction of this steel, the sawdust obtained from a cut right through the body of the meteorite necessarily affords a better average sample for analysis than a portion cut off from one part of the meteorite. An allowance of course is easily made for the iron thus introduced. No oil or other lubricant was used in cutting and the saws were new and perfectly clean.

The material of this meteorite rusts very quickly, so much so that it was difficult to procure photographs of the polished and etched sections before a brown film had formed, although various precautions were taken to prevent the rusting from taking place, but no exudation of iron salts was observed.

After polishing the sections, it was found that etching with bromine water gave the most detail, after treatment with bromine the sections were well rinsed and placed in ammonia or caustic potash and then packed in quicklime, in other cases they were also immersed in strong spirit and dried quickly, some also were dried for a long period in a water oven and coated with collodion, but in spite of all the care exercised, they sooner or later became coated with a brown film of rust.

The best results were obtained by keeping the sections in kerosene oil. This treatment will, of course, prevent the sections from being employed for the determination of carbonaceous matter and of occluded gases, but it was thought that the preservation of the sections was of more importance than the possibility of their being needed for those purposes.

Seven parallel slices in all were cut off, and one side of each section was planed, polished, etched and photographed. The outer slices are quite small in area, as they are taken from the nodosities or projecting portions of the mass. The inner sections, of course gradually became larger, and had to be left thicker for fear they should break in the process of cutting; the process of cutting became very difficult and hard upon the saw with the increase in the areas of the sections.

The idea in making the series of parallel sections, each of rather less than half inch in thickness, was not only that the changes in the structure could be examined, but

also that from the sections (or from the photographs of the sections) it might be possible to build up a model so as to show the internal structure and arrangement of the crystals, enclosed nodules, fissures, etc., but as it is very difficult to recognise parts of the structure as being common to any two of the sections, the information obtainable from a reconstruction would not perhaps be of much importance as I had hoped. More information would be obtained if both sides of each section had been polished and etched, but so far there has only been time to do one side of each.

I do not think this has been previously done for many meteorites, the Boogaldi siderite was so treated, but only one section was published, see Journ. Roy. Soc. N.S.W., 1902; as a rule, pieces appear to be indiscriminately sliced off for examination, and for exchange or sale; and usually only one of them is photographed. In some siderites the structure is fairly uniform throughout and they may not repay the trouble and expense, but in this instance I think that the differences in crystalline structure, distribution of nodules, etc., shown on passing from the exterior to the interior are worth the extra labour expended in making the series of sections, and even if the slices become dispersed the consecutive series of photographs will be available for future examination.

By an oversight all the polished and etched surfaces do not face one way. The disposition of the crystals is, in part clearly octohedral, but there are other crystals, notably some of the large ones, which do not conform to this arrangement.

Description of the Plates.

Plates 11 and *12* are reproductions of photographs of the exterior of the meteorite reduced to one half of the natural size. The dimensions of some of the principal pits and

holes are given on the plates, as it is not possible to judge of their depths from the illustrations.

Plate 13, shows the internal structure of the main mass of the meteorite after the removal of the seventh slice, reduced to one half the natural size. It shows two well marked nodules, one indicated by the letters *a.a.* is more or less pentagonal in outline, and contains a central nucleus probably of kamacite and other smaller nodules; the second, marked *b.b.*, is almost circular in section.

Plate 14, is from an enlarged photograph (2 diameters) of the two nodules *a.a.* and *b.b.* The spherical nodule is shown to be fissured roughly into quadrants, and the usual investing films of lustrous kamacite are clearly shown. There are numerous very remarkable long narrow bright lines of tænite, they are also visible in the other photographs but not so distinctly. When copper sulphate is used for etching, these very fine lines are apt to be lost. It will be noticed that these fine lines cut across many of the larger crystals. Many more details are shown in the original photograph, and some can be seen in this plate by the use of a lens. The dark crystals or portions of crystals are metallic looking (like the rest of the meteorite) before etching.

Plate 15. This represents the etched surface of the seventh slice reduced to one half the natural size. The nodules *a.a.* and *b.b.* do not extend into this, and it is not quite clear whether any portions of the crystals seen in *Plate 13* are present in this section.

Plate 16 represents the sixth slice reduced to $\frac{12}{20}$ of the natural size. The hole in the lower part is due to one of the cavities having been cut across.

Plate 17 represents the fifth slice reduced to $\frac{12}{20}$. The comparatively large crystals of kamacite are arranged in remarkable parallel lines.

Plate 18 represents the fourth section also reduced to $\frac{12}{20}$.

Plate 19. This section, the third in order, is of the natural size, was etched by copper sulphate. It shows a nodule *a.a.* of troilite; but much of the detail visible in the bromine etched sections is lost. The black semicircular patch to the left is a large troilite nodule, invested with bright kamacite.

Plate 20 is an enlargement, by five diameters, of the part of the above section containing the nodule *a.a.* It has a dark roughly pentagonal nucleus, which may be a crystal. In the lower left hand corner is a portion of a troilite nodule invested with bright kamacite.

Plate 21 represents the second section enlarged one and a half diameters.

Plate 22 is from the first section enlarged two diameters.

All the sections were etched by bromine water except the third shown in *Plate 19.*

On the whole the structure of this meteorite appears to be unique, but it requires further investigation, and this brief account can only be regarded as a preliminary one. The troilite nodules were more readily acted upon by the bromine and their etched surfaces are distinctly depressed below the level of the rest of the meteorite.

Chemical Composition.

Resinous Matter.—Some of the sawdust, which had not come into contact with oil or lubricant of any kind was extracted with benzene, which had been redistilled until it left no residue on evaporation in a clock glass. In one experiment it was found that 50 gms. of the sawdust yielded to the benzene ·004 gm. of a resinous looking substance, slightly tinged with brown, which when heated on platinum foil melted, burnt with a smoky flame and left no residue. The quantity was insufficient for further

examination. The residue from the hydrochloric acid solution was also extracted with specially purified benzene, this extract also yielded a small quantity of similar resinous looking combustible matter.

In another experiment, the residue insoluble in sulphuric acid from 100 gms. of the planings (from slice No. 7) was extracted with pure benzene and yielded ·0129 gm. of a thick yellow oil, which when heated on platinum foil burnt with a smoky flame. No nitrogenous odour was perceptible on igniting the resinous residue, hence it is apparently not a nitrogen compound.

It is assumed by some, even recent writers, that the presence of combustible matter in meteorites proves that they have not been subjected to a high temperature, but this does not necessarily follow, it merely proves that the interior has not been exposed at a high temperature to the action of oxygen; the presence of carbon in cast iron and steel and of bituminous matter in igneous lavas etc., refutes this idea.

The composition was found to be:—

Iron...	88·605
Nickel	9·741
Cobalt	·474
Copper	·009
Phosphorus	·429
Sulphur	traces
Resinous matter	·008
Insoluble in HCl.	·720
Total	99·986

The amount of phosphorus is high, and it indicates the presence of more schreibersite than usual. If schreibersite be taken as $(FeNi)_4P$ the ·429% of P would represent 3·61% of schreibersite. Some of the very bright crystals seen in

the photographs may consist of this mineral, but they have not yet been isolated and examined chemically. Carbon is present, but the amount has not yet been determined, antimony, tin, arsenic and chromium were not found.

Tests for Gold and the Platinum Metals.—Ten gms. of the sawdust from slice No. 1 were treated with dilute pure hydrochloric acid. A residue weighing ·3665 gm. was left. After grinding this residue in an agate mortar, it was seen to contain a number of bronze coloured metallic looking particles, many of which were triangular in outline and about ·5 to 1 mm. across; they were but feebly magnetic and dissolved readily in nitric acid. They appear to be crystals which have been flattened in the mortar.

The residue insoluble in hydrochloric was partly soluble in nitric acid, on adding ammonia to the nitric acid solution it became blue from the presence of nickel; copper was not found in this solution. On grinding the black residue left by the nitric acid, some minute white metallic particles which streaked the mortar were detected. As they were insoluble in both hydrochloric and nitric acids the probable presence of a platinum metal is indicated.

The hydrochloric acid solution from the above 10 gms. was diluted and treated with hydrogen sulphide and a precipitate was obtained weighing ·0125, this was ignited to remove sulphur, and to oxidise copper and similar metals, and ground in an agate mortar, when a few specks of a white metal insoluble in nitric acid were obtained, and therefore presumably a platinum metal.

Next 10 gms. of the sawdust from slice No. 2 were treated in the same way, and a residue weighing ·4472 gm. was obtained; after treating this with nitric acid two specks of a yellow coloured metal were left, these were twice treated with nitric acid and evaporated to dryness without dissolving, and are therefore presumably gold. The hydro-

chloric acid solution from this second lot of 10 gms. yielded a precipitate with hydrogen sulphide weighing ·0316 gm., this was ignited and ground in an agate mortar and yielded streaks of a white metal, which disappeared on treatment with nitric acid.

In a third experiment 100 gms. of the sawdust from slice No. 6 were treated with hydrochloric acid, and the insoluble residue treated as before. A few specks of yellow metal insoluble in nitric acid were left, these were again evaporated down to dryness with nitric acid and remained undissolved, so that they appear to be gold.

One hundred gms. of planings from slice No. 7 were treated with pure sulphuric acid, the acid was previously treated with hydrogen sulphide to remove any platinum which might have been present; the insoluble residue amounted to 2·7952 gms.; neither gold nor platinum metals were found in it.

One hundred gms. from slice No. 7 were dissolved in hydrochloric acid to which some sulphur dioxide had been added to remove any free chlorine. The insoluble residue amounted to 2·3777 gms. and yielded one speck of white and one speck of yellow metal, both were soluble in nitric acid.

Ten gms. of the planings from slice No. 7 were treated with acetic acid, the insoluble residue amounting to ·2594 gm. resembled that left by hydrochloric acid, and was apparently made up of schreibersite, perhaps some cohenite, and a little carbon. It contained 47·02% of iron, 25% of nickel and 3·42% of phosphorus; it is intended to obtain more of this acetic acid residue and submit it to further examination.

NOTES ON SOME NATIVE DIALECTS OF VICTORIA.

By R. H. MATHEWS, L.S.,

Corres. Memb. Anthrop. Soc., Washington, U.S.A.

[With one Illustration.]

[*Read before the Royal Society of N. S. Wales, October 7, 1903.*]

HAVING collected some additional details respecting the grammatical structure of the Woïwūrru, Būnwūrru, Lēwurru, Buibatyalli, Nŭndatyalli, and Yabula-yabula dialects, spoken by the aboriginal inhabitants of central and western Victoria, I beg to submit the result of my labours for publication in your Journal. The information now supplied is of considerable importance, as extending and confirming my previous researches among the remnants of the native tribes of Victoria.[1] Now is the time, while the opportunity still exists, to endeavour to preserve some record of the speech of the Australian Aborigines. I have abbreviated my notes as much as possible, in order to bring the subject within the space at the disposal of this Journal, but it is hoped that the present article will be found sufficient for the purpose intended, if it be read in connection with my former memoirs on the speech of the aboriginal tribes of Victoria.

The system of orthoëpy adopted herein is the same as that used in my "Language of the Būngandity Tribe of South Australia," already published in this volume, to which the reader is referred, pages 59 to 74.

[1] "The Aboriginal Languages of Victoria," with Vocabularies, Journ. Roy. Soc. N.S.W., Vol. XXXVI., pp. 71 - 106, in which I dealt with six of the native tongues. See also my "Yotayota Language" and "Burēba Language," spoken within the Victorian frontier on the Murray River, Journ. Roy. Soc. N.S.W., Vol. XXXVI., pp. 167 - 175, with Vocabulary at pp. 179 - 190.

The Woiwurru and Bunwurru Dialects.

In a former article I defined the boundaries of the territory within which these dialects were spoken, together with a short conjugation of one of their verbs. I now wish to make a few remarks on their nouns. These dialects are named after their equivalents for the English word "no," to which is affixed the native word "wūrru," signifying "lip," and hence speech. The names of the dialects therefore mean, "Wo-i speech" and "Būn speech," respectively. This peculiarity of naming a language after its negative adverb obtains among several tribes in Victoria, as well as in New South Wales, already reported by me.

The following information respecting nouns in the Wo-i-wūrru are supplied for the purpose of comparison with other Victorian languages described by me in former papers. Number and gender are so nearly the same as in the Thāgu-wūrru and Wuddyāwūrru, that they will not be introduced here. Only a few of the cases of nouns need be illustrated:

The nominative merely names the object under attention, and then the noun remains unchanged, as guli, a man; wangim, a boomerang; guang, an eel.

Causative—Gulia guang bakunirra, a man an eel caught.

Genitive—The possessor and the chattel are both declined guliagu wangimñuk, a man's boomerang.

Everything over which ownership can be exercised is subject to inflection, by possessive affixes to the noun, for number and person, as, Wangimek, my boomerang, and so on.

The remaining parts of speech follow substantially the same grammatical rules which have been reported by me among the adjoining tribes on the north and west.

The records which I have preserved of the Wo-i-wūrru grammar were gathered by me from "Billy Bērak," a member of the Yurundyeri sub-tribe, which formerly roamed

over the country watered by the Yarra and Plenty rivers, including the site on which Melbourne and its suburbs now stand. This man died on the 15th August last at Coranderrk Aboriginal Station, near Healesville, Victoria, and was buried in the cemetery there the following day. When I was at Coranderrk in 1898, Mr. J. Shaw, the manager, told me he thought "Billy Bĕrak" was then about 75 years old, which would make his age at the time of his death 80 years. He was the last pure-blood survivor of his tribe, and spoke the Woïwurru tongue, but he also understood the Būnwūrru. He belonged to the *wa* (or crow) totemic division, for particulars respecting which, and the laws of intermarriage and descent, the reader is referred to an article I contributed to the Anthropological Society at Washington in 1898.[1]

I have been several times at the Aboriginal Station at Coranderrk, and on each occasion visited "Billy Bĕrak" at his hut there, and obtained from him all available information respecting the language and initiation ceremonies of his people. He was a merry old fellow, and frequently sang some of his native chants for my benefit. Incidentally he told me that he had been several years in the Police Force as a "tracker"—that he had been thrice married, but had no children living. He remembered the visit of Batman to Port Phillip Bay and the Yarra river, although himself only a lad at the time. My last visit to Coranderrk[2] was in April of the present year. Poor old "Bĕrak" was

[1] "The Victorian Aborigines: their Initiation Ceremonies and Divisional Systems," *American Anthropologist*, Vol. xi., pp. 325 - 343, with map of Victoria.

[2] Coranderrk is a corruption of *korranderrak*, the aboriginal name of a small tree or shrub usually found near watercourses. Numbers of these trees grow along the banks of Badger Creek, on which Coranderrk Aboriginal Station and grounds are situated. It is commonly known as the "mint bush," and its botanical name is *Prostanthera lasiander*, of the natural order *Labiatæ*.

. . . persuaded him to sit on a chair ... a photographic acquaintance took ... this is the last photograph of the last ... tribe, I submit it for publication.

... Berak, the last of the Yarra River tribe, Victoria. (From a photograph taken four months before his death).

... Rev. G. W. Torrance, contributed a short article ... Anthropological Institute of Great Britain on ... of the Australian Aboriginals," in which he supplied ... music of some songs which were sung to him by "Billy ..." Mr. Torrance says the man's voice was "a bari... of average compass."[1]

For the music and words of several songs of the aborigines of the south-east coast of New South Wales, see my "Aboriginal Songs at Initiation Ceremonies."[2]

The Lewurru Dialect.

This tongue prevails about St. Arnaud and surrounding country, and is somewhat similar in grammatical structure to the "Tyattyalli Language" reported by me in 1902,

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[1] Journ. Anthrop. Inst., London, Vol. xvi., pp. 335 – 340.

[2] Queensland Geographical Journal, Vol. xvii., pp. 61 - 63.

although differing more or less in vocabulary. It is thought that a few examples in the different parts of speech will be sufficient. *Le* means "no" and *wurru* "lip."

Nouns.

Number and gender will be passed over.

Case.—Nominative—Kuli, a man. Duan, a squirrel. Kuyun, a spear. Kulkurn, a boy.

Causative—Kulingu kulkurn tyilpin, a man beat a boy.

Instrumental—Kulingu duan bandyin kuyunu, a man killed a squirrel with a spear.

Possessive—The proprietor and the property are both declined. Kulinga kuyunuk, a man's spear.

Adjectives.

These are declined like the nouns for number and case.

Pronouns.

Pronouns have four numbers—singular, dual, trial, and plural. There are two forms to express, respectively, "we," "ours," "us"—the one including both the speaker and the person spoken to, and the other excluding the latter.

The persons of the singular number of the nominative pronouns are as follow :—

Singular	1st Person	I,	Wangek
	2nd ,,	Thou,	Wangin
	3rd ,,	He,	Wanyuk

The other numbers resemble the Tyattyalli. The trial is formed by adding *kullik* to the plural, the same as in that language. The demonstratives and interrogatives are omitted.

Verbs.

In the following conjugation the present tense is given in full; but in the past and future the singular only is taken:—

Indicative Mood—Present Tense.

Singular	1st Per.	I beat,	Tyilpan
	2nd ,,	Thou beatest,	Tyilpar
	3rd ,,	He beats,	Tyilpa
Dual	1st Per.	We incl., beat,	Tyilpangul
		We excl., beat,	Tyilpangulung
	2nd ,,	You beat,	Tyilpawul
	3rd ,,	They beat,	Tyilpabullang
Trial	1st Per.	We incl., beat,	Tyilpangurkullik
		We excl., beat,	Tyilpangandangkullik
	2nd ,,	You beat,	Tyilpawatkullik
	3rd ,,	They beat,	Tyilpanatykullik
Plural	1st Per.	We incl., beat,	Tyilpangur
		We excl., beat,	Tyilpangandang
	2nd ,,	You beat,	Tyilpawat
	3rd ,,	They beat,	Tyilpanaty

Past Tense.

Singular	1st Per.	I beat,	Tyilpinan
	2nd ,,	Thou beatedst,	Tyilpinar
	3nd ,,	He beat,	Tyilpin

Future Tense.

Singular	1st Per.	I shall beat,	Tyilpinyan
	2nd ,,	Thou shalt beat,	Tyilpinyar
	3rd ,,	He shall beat,	Tyilpiñ

Imperative—Beat, Tyilpak

Reflexive—I am beating myself, Tyilpillangan

Reciprocal—

We, dual incl., are beating each other, Tyilptyerrangul.

The prepositions, adverbs and exclamations are omitted, because they closely resemble the corresponding parts of speech in the Wūtyuballeak tribes to the westward.[1] The Lewūrru and Tyeddyuwūrru are sister tongues.

[1] See my "Native Languages of Victoria," American Anthropologist, Vol. v., N.S. pp. 380 - 391.

THE BUIBATYALLI DIALECT.

The Buibatyalli is spoken about Hopetoun and Lake Hindmarsh, in the north-west of Victoria. It is a dialect of the Tyattyalli, and the leading elements only will be touched upon.

NOUNS.

Nouns have the singular, dual, trial and plural, which are expressed by words meaning two, three, or several placed after the noun.

Gender—Wutyu, a man. Laiuruk, a woman. The sex of animals is shown by adding words signifying "male" and "female."

Case is generally the same as in the Tyattyalli, but with differences in the suffixes, as in the following few short examples.

Causative—Wutyulu gal burdin, a man a dog beat.

Genitive—There is a double form in this case, one for the possessor and another for the possessed :—Wutyugity kirramuk, a man's shield.

The name of every object over which one can exercise ownership may be inflected for person and number, as Kirramik, my shield. Kirramanguruk, our (plural) shield, and so on.

Adjectives are declined like the nouns.

The pronouns resemble those of the Tyattyalli and Lēwūrru, and will be passed over. There is a double form of the first person in all the numbers beyond the singular.

VERBS.

A few brief examples will suffice to show their similarity in conjugation to neighbouring tongues.

Present	I tell,	Kēnan
Past	I told,	Kēinan
Future	I will tell,	Kēinyan

With an objective pronominal affix we get:

(Someone) spoke to me, Kōinniñ.

The remaining parts of the verb are, with slight differences, the same as in the Tyeddyuwurru language, reported by me elsewhere.

Some prepositions and adverbs can be inflected for person and number as in my "Thoorga Language."[1]

The Nundatyalli Dialect.

The country in which this tongue is used is situated north of the Būngandity-speaking people, and extends northerly towards Horsham. The grammatical constitution resembles partly the Būngandity and partly the Tyattyalli. The nouns, prepositions, adverbs, etc., in addition to the verbs and pronouns, take inflection for person and number, as in my "Tharumba Language."[2]

Nouns.

Druah, a man. Druahaga bopop dakin, a man a child beat. Druahagaty gattimgattimuk, a man's boomerang.

The other parts of speech are omitted for the present.

Some Victorian dialects are named after the word *tyalli*, meaning "tongue," which the people have recognized as the source of speech. Nŭndatyalli, Buibatyalli, Tyattyalli, are examples of languages which have received their names in this way. In Gippsland certain dialects are designated by means of their word *dhang*, "talk," or "speech," with a qualitative adjective, thus,—Dhang-māk, great or wide speech; Dhang-gwai, rough speech, and so on. In the south-western districts of Victoria, some of the dialects are distinguished by the aboriginal equivalent of our second personal pronoun. For example, the Dhahurtwūrru is also called *Ngutuk*, "thou," by neighbouring tribes. Other

[1] Queensland Geographical Journal, Vol. XVII., 49 – 61.

[2] Ibid., Vol. XVIII., pp. 58 – 61.

languages are named after the negative adverb, as mentioned in an earlier paragraph of the present article.

THE YABULA-YABULA DIALECT.

This language is spoken on both sides of the river Murray, from Echuca downwards for some distance. It is a dialect of the Yota-yota, a portion of the grammar of which I briefly outlined last year.[1] Both these tribes are located partly in Victoria and partly in New South Wales. Although more or less different in vocabulary, the declensions of the nouns and adjectives are substantially the same in the Yabula-yabula as in the Yota-yota, and will therefore be omitted in this paper. But I succeeded in obtaining much fuller lists of pronouns of a varied and interesting character which I should like to publish for comparison with primitive languages in other parts of the world. Yabula means "no."

PRONOUNS.

There is a set of nominative pronouns for use with transitive verbs, and another set for intransitive verbs, as in the following table. There are "inclusive" and "exclusive" forms for the dual and plural in the first person :—

			Transitive.	Intransitive.
Singular	1st Per.	I,	Nguttha	Nga
	2nd ,,	Thou,	Nginnak	Nginna
	3rd ,,	He,	Daluk	Da
Dual	1st Per.	We, incl.,	Ngalnginnak	Ngalngin
		We, excl.,	Ngullak	Ngulla
	2nd ,,	You,	Bullak	Bulla
	3rd ,,	They,	Damulak	Damulu
Plural	1st Per.	We, incl.,	Nyuandak	Nyuanda
		We, excl.,	Nyanak	Nyana
	2nd ,,	You,	Nhurak	Nhura
	3rd ,,	They,	Damnak	Damna

Again, there are emphatic forms of these pronouns, equivalent to "myself," or, "I alone." etc. They are made

[1] Journ. Roy. Soc. N.S.W., Vol. xxxvi., pp. 197 – 172.

by adding *ngo* to the pronouns in the foregoing table. Examples in the singular number will be sufficient:

Singular	1st Per.	Myself,	Nguttbango	Ngango
	2nd ,,	Thyself,	Nginnakngo	Nginnango
	3rd ,,	Himself,	Daluknngo	Dāngo

The following table exhibits the pronouns of the possessive and objective cases:—

Singular.	Possessive.		Objective.	
1st Per.	Mine,	Nyini	Me,	Ngannin
2nd ,,	Thine,	Nguni	Thee,	Ngunun
3rd ,,	His,	Danin	Him,	Dēya
Dual.				
1st Per.	Ours, incl.,	Ngalngun	Us, incl.,	Ngalngunan
	Ours, excl.,	Ngullun	Us, excl.,	Ngullunan
2nd ,,	Yours,	Bullun	You,	Bullunan
3rd ,,	Theirs,	Damalunya	Them,	Bullēya
Plural.				
1st Per.	Ours, incl.,	Nyuandun	Us, incl.,	Nyuandunan
	Ours, excl.,	Nyanun	Us, excl.,	Nyanunan
2nd ,,	Yours,	Nhurun	You,	Nhurunan
3rd ,,	Theirs,	Ngamnyun	Them,	Dhamnan

The demonstratives in this language are numerous, and can, by various combinations, be made to indicate position, direction, distance, person, number, possession, etc.; but these, and also the interrogatives, must be omitted.

Verbs.

Verbs have modifications for the tenses, but person and number are shown by the pronouns, as in the following few examples, including transitive and intransitive verbs:—

Present	I speak,	Nga loatbaty
Past	I spoke,	Nga loatbatybenga
Future	I shall speak,	Nga loatbatyak

and so on through all the persons and numbers.

Reciprocal.

We, dual, speak to each other,	Ngalngin loatbadhan
We shall speak to each other,	Ngalngin loatbaddherak

Transitive verbs take transitive pronouns:

Present	I strike,	Ngutttha nyinnin

Past	I struck	Ngutthabenga nyinnin
Future	I shall strike,	Nguttha nyinniak

In the past and future tenses of the verbs in all the dialects treated in this article, there are forms to indicate that the act described was done in the immediate, recent, or remote past; or that the act will be performed in the proximate or more or less distant future; that there was, or will be, a continuance of the action, and many other modifications which will not now be touched upon.

The grammatical functions of the prepositions, adverbs and exclamations of the Yabula-yabula are so similar to those of other languages in that locality already reported by me, that they will at present be passed over.

Conclusion.

Victoria is the only Australian State of which it can be said that no grammar of the languages of its native inhabitants had ever been published, until my "Aboriginal Languages of Victoria" appeared last year.[1] Chiefly through the medium of this Journal, and also by the kind support of other societies, I have now recorded and published for the first time, the elements of the grammar of sixteen of the native dialects of Victoria, which have been selected from different districts throughout that State, for the purpose of being representative of the speech of every tribe. It may therefore be said that, practically, I have dealt with the constitution of all the aboriginal tongues of Victoria. The whole of this work has been the result of my own individual investigations, every word in the grammars and in the vocabularies having been noted down by me personally from the lips of the native speakers.

The social organization, illustrating the intermarrying divisions of the community, and also several highly interesting ceremonies of initiation among Victorian tribes, as well as many native customs, have been fully described by me in other publications.

[1] Journ. Roy. Soc. N.S.W., Vol. xxxvi., pp. 70 - 106.

ON SOME FURTHER OBSERVATIONS ON THE LIFE-HISTORY OF *FILARIA IMMITIS*, LEIDY.[1]

By THOS. L. BANCROFT, M.B., *Edin.*

[*Read before the Royal Society of N. S. Wales, November 4, 1903.*]

I COMMUNICATED to the Society in June 1901, a paper entitled "Preliminary notes on the intermediary host of *Filaria immitis*, Leidy," since then I have had the opportunity of following up several points in the life-history of this parasite, which remained to be elucidated.

It was evident that the young or larval filariæ, arrived at maximum development, as far as their life in the mosquito was concerned, passed out, in some way or other, into their final hosts, but the exact manner of exit was a disputed point. I had myself[2] suggested that the worms passed down the proboscis into the wound inflicted by the mosquito; I did not think it possible for such helpless creatures to swim against the blood stream entering the mosquito's stomach by the epipharynx. Afterwards,[3] whilst examining labia of filariated mosquitoes, mounted in water and with a cover glass, it was observed how readily the worms escaped from the apex of the proboscis or labium, and it was suggested that they naturally thus made their exit. Dr. George C. Low considered it probable that the young filariæ passed out of the labium at its base; Grassi, however, could not believe it possible for larval worms, without any special mechanism for boring their way, to pierce the

[1] The expenses of this investigation have been met in part by a grant of £58 from the British Medical Association, London July 25th, 1901.

[2] Proceedings of the Royal Society of N. S. Wales, Vol. XXXIII., p. 62.

[3] Proceedings of the Royal Society of N. S. Wales, Vol. XXXV., p. 44.

integument of the labium; he had an idea of his own to explain their exit from the labium. As is well known, when a mosquito imbibes blood, the labium or sheath of the stylets is bent upon itself, whilst the stylets are thrust deep into the skin; Grassi considered that when a labium containing filariæ was thus buckled up it would be ruptured and the worms extruded. This hypothesis was easily disproved, for upon microscopic examination of the labia of filariated mosquitoes, which had bitten and relieved themselves of parasites, one or more openings were seen in the labellæ, often very apparent owing to the escape of pigment and granular matter; there were no openings elsewhere.

It remained to be proved by actual experiment, that filariated mosquitoes could infect dogs, and it was important to ascertain how long a time would elapse before embryo-filariæ could be detected in the experimental dog's blood. The time taken from the bite of the mosquito until the embryos can be found in the blood is about nine calendar months; in one instance it was only eight and a half months. One dog, which had been filariated, was stolen at eight months, up to which time there were no embryos in its blood. To fix the time as accurately as possible, this experiment was made: a puppy, bred from non-infected parents, was kept away from filariated dogs; on December 30th, 1902, it was put into the mosquito house and 183 filariated mosquitoes, three weeks old, were liberated; the next morning it was found that 70 mosquitoes had bitten; that was the only infection the dog received. After seven months had elapsed, its blood was examined weekly, but it was not until October 1st, 1903, *i.e.*, nine months, that the embryos were detected; the dog was then killed and the heart and lungs examined, there were 32 fully developed filariæ, sixteen males and sixteen females, in the right ventricle and pulmonary artery.

I was desirous of ascertaining, (although the chance of doing so was very slight), where in the dog's body the young filariæ lived before partaking themselves to the heart. I had on several occasions, whilst dissecting filariated dogs, found half grown forms in the lungs. One dog, which had been bitten by 103 filariated mosquitoes and in whose body there would be at least fifty worms, was examined three months afterwards; the tissues were sliced with a knife or cut into small pieces with scissors in hope that, were a worm cut, it might move or its body protrude and thus attract the eye; nothing however was seen. Mature filariæ scarcely move when cut across, and might readily be overlooked, so it can be understood how such delicate bodies, as young filariæ, might easily escape detection. It is probable that the young filariæ live in minute arteries in the lung. Another filariated dog was examined seven months after infection, full grown filariæ, both males and females—the females ten inches long, which is the maximum length they attain to—were found in the heart; the uterine tubes were devoid of embryos however. The parasite is at this date, probably sexually mature, but a month or two must elapse before embryos are developed.

Two dogs used as a "control" in this investigation, lasting over a period of two years, remain free from filariæ.

Explanation of Diagrams.

Fig. 1—Diagram of a "House Mosquito," *Culex fatigans*, Wied., in the act of imbibing blood, drawn from photomicrographs.

Fig. 2—Diagram of the head of a mosquito imbibing blood, depicting the escape of a young filaria into the skin along side the stylets. A, thorax; B, head; C, clypeus; D, skin; E, eye; F, filaria; H, labellæ; I, antenna; L, labium; N, neck; O, occiput; P, palpi; S, stylets.

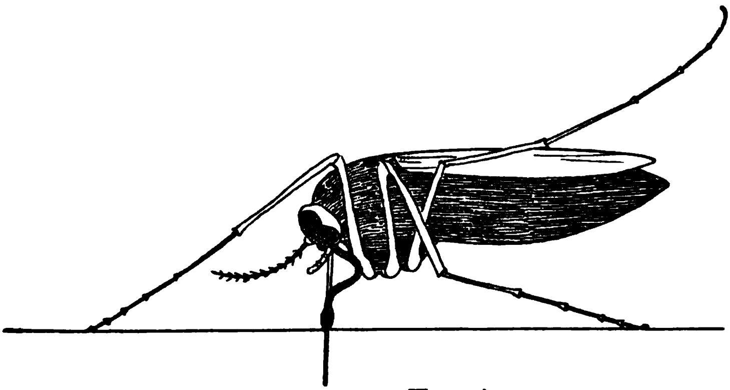


Fig. 1.

Attitude of a "House Mosquito," assumed in the act of imbibing blood.

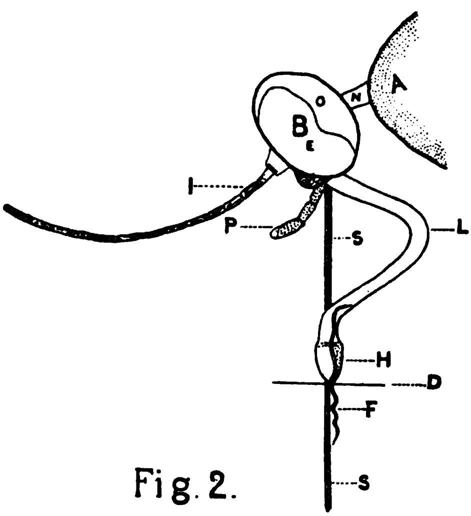


Fig. 2.

A, thorax; B, head; C, clypeus; D, skin; E, eye; F, filaria; H, labella; I, antenna; L, labium or proboscis; N, neck; O, occiput; P, palpi; S, stylets.

On the ELASTIC RADIAL DEFORMATIONS in the RIMS and ARMS of FLYWHEELS, and their Measurement by an Optical Method.

By A. Boyd, B.Sc., B.E., Stud. Inst. C E.

[Communicated by Prof. W. H. Warren, Wh. Sc., M. Inst. C.E.]

[*Read before the Royal Society of N. S. Wales, August 5, 1903.*]

The investigation described in the following pages was undertaken with the object of supplying data for the comparison of the results given by the present flywheel theories with the results of experiment, and for the development of a more exact theory. The effect of curved arms and of flanged joints is also investigated. Hitherto the subject has been dealt with only in a theoretical fashion, no definite measurements of the actual expansions of the rim having been attempted.

One of the best known treatments of the question in English is that given by Professor Unwin in his text-book on Machine Design.[1] He discusses the case of a homogeneous flywheel running at uniform speed, and deduces expressions for the shearing force, bending moment and tension in the rim. This was worked out in a simpler manner some time afterwards by Professor Lanza.[2] These theories are discussed and applied to actual cases hereinafter. Two papers on the subject were contributed by Mr. J. B. Stanwood,[3] in which attention was drawn to the stresses produced in flywheel rims by the bending of the rim, and a method of treating the case was pointed out,

[1] Elements of Machine Design, Part II.

[2] Trans. Am. Soc. Mech. Engineers, Vol. xvi., p. 208.

[3] Trans. Am. Soc. Mech. Engrs, Vols. xiv. and xv.

but the method was erroneous as it was based on the assumption that the extension of the arms is such as to render the stresses due to bending one half of what they would be if the arms did not stretch at all, an assumption for which there is apparently no foundation.

The only experimental work known to the writer is that which was carried out in 1898 and later, at the Case School of Applied Science by Mr. C. H. Benjamin.[1] These experiments were carried out on small cast-iron flywheels 15 inches and 24 inches in diameter, which were tested to destruction, the speed at which they burst being determined. Each wheel was a scale model of some actual flywheel designed by a reputable firm. To attain the speed necessary for destruction, use was made of a Dow steam turbine capable of being run at any speed up to 10,000 revolutions per minute. As the speed was too great for the successful use of a tachometer or a counter, a commutator of one break was arranged on the flywheel shaft and this connected through the battery circuit with an ear-phone in an adjoining room. This gave a clear musical tone, but it was found that the audible tone produced by the machine itself when running at a high speed corresponded exactly to the tone in the ear-phone, and so the ear-phone was discarded. Two observers with tuning forks determined the pitch within half a tone, the quarter tones being estimated. By this means it was thought that the error in speed did not exceed 5%. Wheels of various designs were tested—some with three arms or six arms, and others with joints in the rims of various kinds.

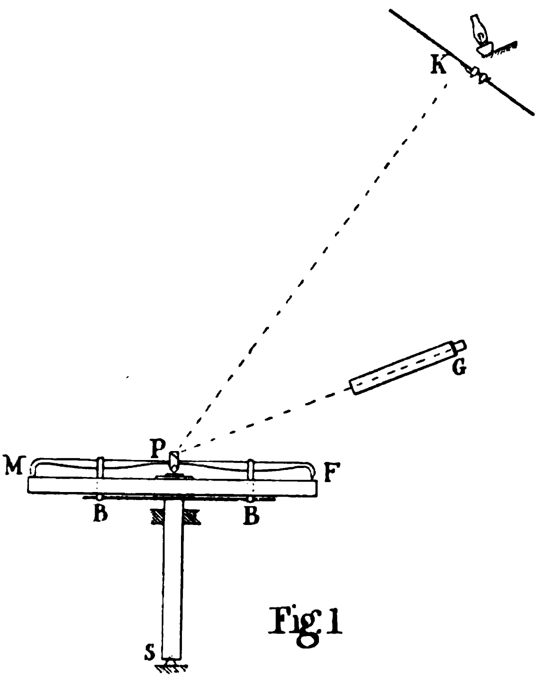
These experiments indicate that, as the segments of the rim between the arms become weaker as beams, either through increase of length or decrease of thickness, there is a falling off in the bursting speed. The shape of fracture

[1] Trans. Am. Soc. Mech. Engrs., Vol. xx., p. 209.

at the outer ends of the arms in all the wheels usually indicated that the rim broke first midway between the arms, and that then the two parts of the rim flew outward and broke off at the arms, thus demonstrating the large effect of transverse loading on the rim due to its centrifugal force.

In the following investigation actual measurements of the deflections of the rims were taken as the speed was increased, so that the behaviour of any wheel at any particular stage of its expansion can be observed. The experimental flywheel to be tested was arranged horizontally, and the deflections of points round the rim measured at various speeds by means of an optical method, which is described[1] by Mr. S. H. Barraclough, B.E., M.M.E., Assoc. M. Inst.C.E. The principle of the method is that of the Martens' mirror apparatus. A steel prism *P* with mirror attached (Fig. 1) stands on the top of the flywheel spindle. On this prism rests a distance rod which is in contact with the rim at diametrically opposite points. One end of the rod *F* is fixed to the rim, the other end *M* merely rests on it. As the rim expands, the distance rod is pulled with it, causing rotation of the mirror. A beam of light given by a lamp behind a knife edge *K* distant about one metre above the mirror is reflected into the field of a telescope fixed on a stand beside the wheel. The general arrangement is shewn clearly in the photograph (Fig. 2). The image of the knife edge is flashed into the field once each revolution, so that at about three hundred revolutions per minute, the image appears as a continuous black edge in the field, and its position can be read on a micrometer scale *G*, in the eyepiece of the telescope. The knife-edge is clamped on a glass scale, graduated to half millimetres, on which it can be moved. The telescope is placed at such a distance from

[1] Proc. Inst. C.E., Vol. CL., p. 398.



K, knife-edge. P, prism with mirror attached. F, fixed end of distance rod. M, moveable end of distance rod. B B, rubber bands on crossbar. S, conical steel pin. G, micrometer scale in telescope.

the mirror that the divisions of the glass scale and of the micrometer scale appear to be of the same size. When the deflection is so large that it cannot be read on the telescope scale, the knife-edge is moved up or down until it is again visible in the field. Since the divisions on both scales appear of equal size, the total deflection is the sum of the movements of the knife-edge on the glass scale and the deflection as read on the telescope scale, provided that there is no deflection while the knife-edge is being moved. In flywheel measurements the deflection is sometimes so rapid that the rim may deflect several divisions while the

knife-edge is being moved. In this case, the movement of the knife-edge on the glass scale was added to the reading on the telescope scale just before the knife-edge was moved. Then, if there had been no deflection of the rim while the knife-edge was being moved, this should give the reading of the telescope scale after the knife-edge had been moved. This usually was not the case, the difference being the deflection of the rim during the movement, *e.g.* zero reading of telescope scale was 49; deflection took place down to 2. The knife-edge, which was at 4·30, was shifted, making the reading on the telescope scale 40. The knife-edge was found to be at 470 on glass scale, *i.e.* it was moved 40 divisions. Then $40 + 2$ should have been the reading on the telescope scale after the movement. But it was found to be 40, so that the deflection during the movement was two divisions.

Mr. Barraclough and the author carried out a number of preliminary experiments in order to arrive at a satisfactory form of distance rod. Three forms of rod were tried (see figs. 3, 4 and 5). These were all constructed of steel, the first and third being attached to the rim by a pair of chisel points, while the second was held by a hardened steel set screw. The distance between the chisel points in the case of the first rod was 0·6 inch, and in the case of the third 0·45 inch. Great care was taken in balancing the rods both in a horizontal and vertical plane; the rods (figs. 4 and 5) were counterbalanced in a vertical plane by means of pieces of metal soldered to their upper faces, making them symmetrical, while the rod (fig. 3) was counterbalanced by means of a coil of copper wire (equal in weight to the terminal bent portion of the rod) wound on the upper part of the small vertical steel bar which acted as a safety arrangement to prevent the rod from slipping off the rim.

Fig. 2—Photograph of General Arrangement.

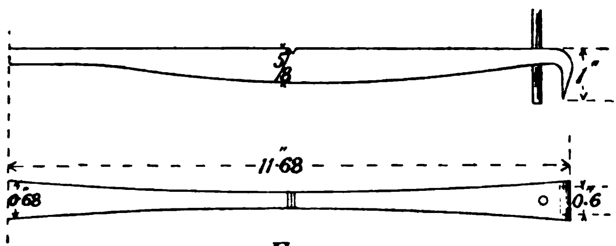


Fig. 3

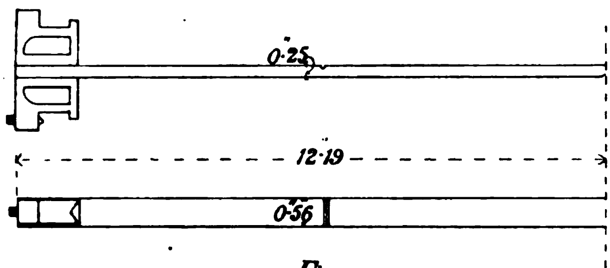


Fig. 4.

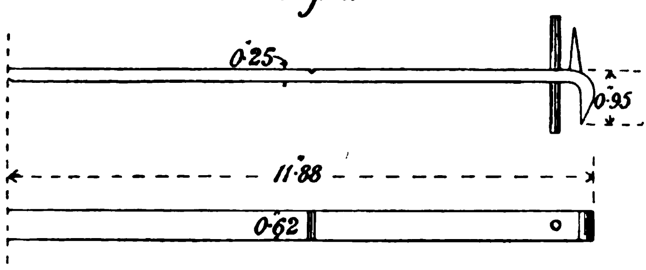


Fig. 5

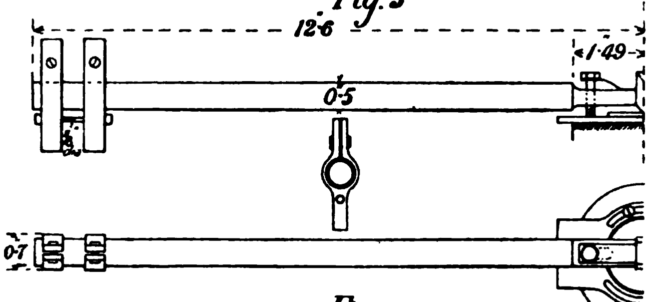


Fig. 6.

These rods were originally kept in position by a pair of steel shackles (see fig. 2) which exerted a vertical pressure on the rod midway between the boss and the rim. The shackles were attached by set-screws to a cross-bar bolted on the underside of the boss (see figs 1 and 2), a little slackness being left in the screws, so that the shackles could move slightly through a small vertical arc. This cross-bar was attached to the boss by two set-screws passing through circular grooves in the cross-bar, so that it could be moved round into any desired position. These shackles were found to be unsatisfactory, owing to the fact that their centrifugal force caused movement of the rod. In consequence, half-inch rubber bands were used in their stead, and were found to be quite satisfactory. The vertical pull of each band was eight pounds. The rods shewn in figs. 4 and 5, owing to their shallow section, were subject to great bending. This was found after a number of trials to mar the results, so that these rods were rejected in favour of the rod shown in fig. 3, which was much more rigid than the others.

In addition to these, the author has constructed a rod of aluminium (fig. 6), which was considerably lighter than any of the others, weighing only 7·25 ozs., whereas the rod, shewn in fig. 3 weighed 1 ℔. 3·25 ozs. It consists of two aluminium tubes half an inch diameter united by a short steel bar. The rod is attached to the rim by a pair of aluminium pieces which are clamped to the rim and to the rod by means of set-screws. The shape of these pieces is shewn in the end view of the rod (fig. 6).

Pressure is applied to the rod directly over the prism by means of a spring held by a pair of set-screws passing through slots in the steel central portion of the rod. The set-screws are screwed into a short moveable cross-bar on the upper side of the boss. This rod was made towards the end of

the experiments, only a few trials were made with it as it was considered advisable to complete them with the original rod (fig. 3). Its advantages are absence from bending, and extreme lightness; moreover, when different wheels are tested it is at once adaptable, whereas in the case of the pointed rod, it is necessary to trim the end of the spindle in order that the rod may rest on the rim and on the prism at the same time. All the tests described in the following were carried out with the distance rod shewn in fig. 3, as it was the most satisfactory of the steel rods, owing to its rigidity and to its having the smallest extension, as seen later.

To find the lineal deflection equivalent to one scale division: The correct expression for the extension as measured by the Marten's mirror apparatus is given by Mr. G. H. Knibbs, F.R.A.S.,[1] and it is directly applicable to the method in question. It is

$$\frac{e}{R} = \frac{l}{2L}\frac{\cos 2\omega}{\cos\omega}\left(1 + \frac{l}{2E}\sin\omega \pm \frac{3}{4}\frac{l}{L}\tan^2\omega\right).$$

Where e = extension.
R = depth of prism.
L = distance between scale and mirror.
E = half length of distance rod.
l = distance between knife-edges.
ω = angle of rotation of line joining them.

In the present case, $R = 0{\cdot}300$ inch, $L = 1010$ mm. Thus, taking the approximate value for the deflection equivalent to one scale division, we have

$$e = \frac{0{\cdot}3}{2\times 2\times 1010}$$

since each division = 0·5 mm., *i.e.*, $e = 0{\cdot}000075$ inch.

[1] Journ. Royal Society, N.S.W., Vol. XXXI., 1897 p. 98.

It will be found that the value of ω is so small that the second portion of the expression may be considered unity, thus

$$\omega = \frac{1}{4040} \text{ in circ. meas.} = 50'' \text{ about.}$$

$$\sin \omega = \cdot 00029 \text{ ; } \cos \omega = 1 \cdot 00000.$$

$$\cos 2\,\omega = 1 \cdot 00000 \text{ ; } \tan \omega = \cdot 00029.$$

$$\text{thus } \frac{\cos 2\,\omega}{\cos \omega} = 1 \text{ and } \frac{1}{2\,E} \sin \omega = 0 \cdot 000004.$$

The correction is thus quite negligible.

In this method of measuring, it is evident that the distance rod will extend under the action of its own centrifugal force. The extension of the portion between the prism and the free end of the rod will have no effect on the mirror, whereas the extension of the portion between the fixed end and the prism will cause rotation of the mirror. The deflection as read in the telescope must therefore be corrected for this extension, the correction being of plus or minus sign according as the mirror is facing towards the fixed or moveable end of the rod.

The extensions of each rod for a given range of speed were worked out and plotted in the diagram (fig. 7), the extensions being reduced to scale divisions. The method of calculation is as follows:—

Let M = weight of unit volume of metal of rod.
ω = angular velocity.
R = distance from centre to end of rod.
E = modulus of elasticity of metal.

Then it may be shewn by a process of integration that the expansion of the rod due to its own centrifugal force is

$$\frac{M\,\omega^2\,R^3}{96\,E}$$

Let M_1 be weight of attachments at end of rod distant R_1 from centre, and A = area of cross section of rod. Then

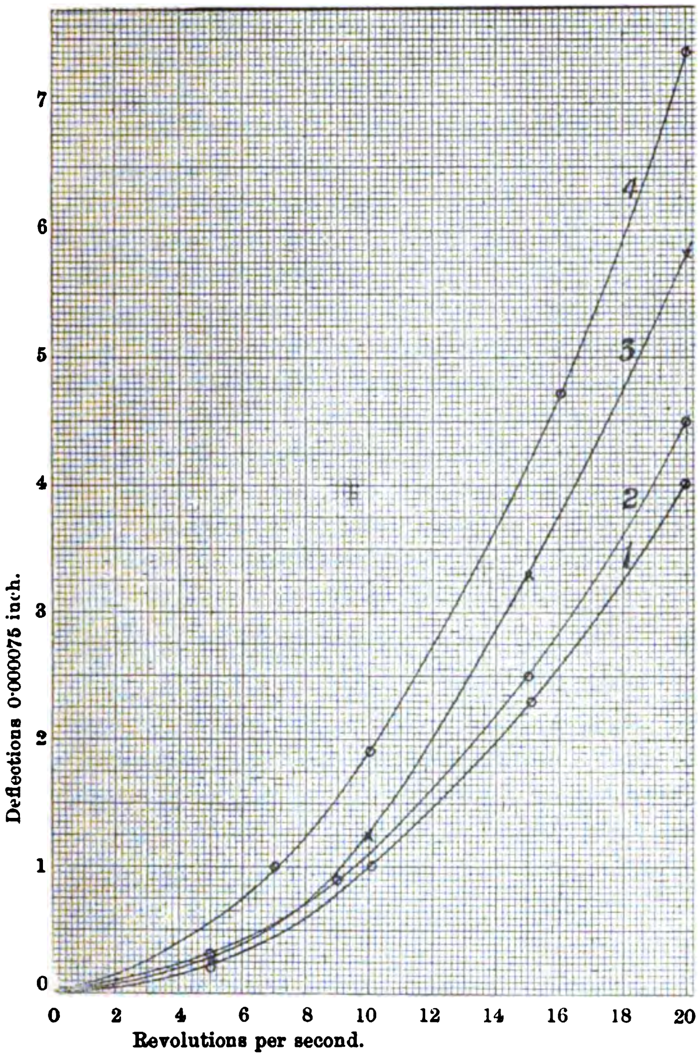


Fig. 7—Calculated Expansions of Distance Rods at Various Speeds.
No. 1. Stiff Distance Rod held by chisel edges to rim.
„ 2. Flat Distance Rod held by chisel edges to rim.
„ 3. Aluminium Distance Rod, clamped to rim.
„ 4. Flat Distance Rod, screwed to rim.

the expansion of the rod due to the centrifugal force of $M_{,}$ is

$$\frac{M_{,}\,\omega^2\,R_{,}^2}{32\,AE}$$

The total extension is the sum of these values.

The distance rods were made of tool steel whose density and modulus of elasticity were very carefully measured. Samples of the same steel bar from which the rods were cut were tested in tension and their elastic deformations determined by means of Martens' mirror apparatus. The following were the average values:—

Coefficient of elasticity 28,747,800 lbs. per square inch.

Weight of steel per cubic inch 0·2798 lbs.

Applying these values to the distance rod used in these measurements we have $R = 0{\cdot}97$ feet.

$$M = 0{\cdot}2798 \times 12^3 \text{ lbs.}$$
$$M_{,} = 0{\cdot}0932 \text{ lbs.}$$
$$R_{,} = 0{\cdot}94 \text{ feet.}$$

The rod was of almost uniform cross section throughout, the average area being 0·180 square inch.

For a speed of one revolution per second the extension was found to be 0·0000007544 inch. The extensions vary as the square of the speed. These values reduced to scale divisions are plotted in the diagram (fig. 7).

In the case of the aluminium rod the coefficient of elasticity was taken to be 10,000,000 lbs. per sq. inch, and the weight per cubic foot 162·5 lbs.

The general arrangement of one of the flywheels with its frame is clearly shown in the accompanying photograph (fig. 2). The flywheels tested by the author in these experiments were six in number:—

1. Three armed wheel with straight arms.
2. Four armed wheel with straight arms.
3. Four armed wheel with curved arms.

4. Six armed wheel with straight arms.
5. Four armed wheel, straight arms, jointed midway between the arms.
6. Four armed wheel, straight arms, jointed along the arms.

Each wheel was approximately two feet in diameter. The wheels were arranged horizontally for convenience of measurement, and were supported on a vertical steel spindle 1·5 inches in diameter, with a taper of 1 in 20 at the top end where it enters the boss of the wheel. The spindle rests at the bottom on an adjustable conical steel pin with hardened point (see fig. 1). This pin is immersed in an oil bath, cast into the lower part of the cast iron frame. The pin may also be oiled by means of a slantwise channel drilled into the lower end of the spindle. At its upper end the spindle passes through a bearing consisting of a brass bush, fixed in the upper portion of the frame. This bush is coned on the outside and has a nut at top and bottom for adjustment. To allow of this adjustment, the bush is cut into by six vertical saw cuts to within an eighth of an inch of its surface of contact with the spindle, in five of them, and completely through at the sixth. These cuts allow the bush to contract on to the spindle as the upper nut is tightened up.

Immediately below the brass bush, a steel collar is attached to the spindle in order to prevent any vertical motion. On the spindle below this collar is a double cast iron grooved driving pulley. Attached to the underside of the boss of the wheel by means of two $\frac{1}{4}$ inch set screws, is a flat steel cross-bar $\frac{1}{4}$ inch thick, $1\frac{1}{2}$ inches broad, and $14\frac{1}{2}$ inches long, with two $\frac{1}{2}$ inch steel bars 3 inches long at the ends. To these bars were attached the shackles which were used in the earlier experiments for the purpose of holding the distance rod in position.

The cast iron frame carrying the spindle is held very rigidly by four $\frac{1}{2}$ inch bolts to a cast iron bed-plate bolted to a concrete foundation 5 ft. by $2\frac{1}{4}$ ft. by 5 feet deep, weighing $3\frac{1}{2}$ tons. This foundation was quite independent of the foundation and floor of the building, so that no ordinary vibrations in the adjoining floor could be detected.

Extreme care was taken in the turning up of the wheels as the accuracy of the results depends on this very largely. The top of the spindle was carefully faced up so as to present an even surface for the prism. Special care was taken in balancing all the rotating parts, and, on resting the spindle with all attached parts on a pair of horizontal knife-edges, no tendency to move in any position was noted.

In all the flywheels tested in these experiments, the rims were of rectangular section, and the arms were of similar and approximately equal cross section all along to avoid difficulties in calculation. For reference, the wheels are lettered according to a kind of Bow's notation *e.g.* for the three armed wheel (fig. 28), the letters A, B, C denoting the bays, and AB, BC, CA denoting the arms, while points on the rim between the arms are referred to as C. 15°, C. 30° and so on, the angle denoting the distance from the arm measured clockwise. The dimensions of the wheels were very carefully determined, those of each arm being given separately in order that any want of symmetry may be shown. The cross-section of the arms was approximately a rectangle with semi-circular ends. Each arm was measured near the boss, at the centre and near the rim. The rim was measured near the arms and at the centres of the bays. The average values are given in the following table :—

Wheel.	Mean Diameter inches.	Dimensions of Rim in inches.			Dimensions of Arms in inches.				Dimensions of Boss in inches.		Weight of wheel in pounds.
		Breadth Radial inches.	Depth, inches.	Area, sq. inches.	No.	Thickness inches.	Breadth inches.	Area. sq. inches.	Diameter, inches.	Depth, inches.	
Three armed; straight arms ... (Fig. 28.)	23·719	0·550	1·153	0·6341	AB	0·421	1·460	0·5802	3·00	1·75	19·28
					BC	0·430	1·532	0·6196			
					CA	0·422	1·501	0·5951			
Four armed; straight arms ... (Fig. 29.)	23·745	0·546	1·153	0·6295	AB	0·443	1·453	0·6077	2·98	2·00	20·75
					BC	0·443	1·443	0·5963			
					CD	0·449	1·447	0·6056			
					DA	0·443	1·445	0·5972			
Four armed; curved arms ... (Fig. 30.)	23·821	0·544	1·152	0·6267	AB	0·421	1·460	0·6038	2·98	2·10	22·06
					BC	0·429	1·508	0·6044			
					CD	0·429	1·492	0·6035			
					DA	0·432	1·484	0·6009			
Six armed; straight arms ... (Fig. 31.)	23·751	0·547	1·147	0·6274	AB	0·435	1·469	0·5976	2·98	2·00	23·66
					BC	0·455	1·501	0·6376			
					CD	0·448	1·482	0·6207			
					DE	0·433	1·455	0·5930			
					EF	0·435	1·487	0·6054			
					FA	0·452	1·467	0·6191			
Four armed wheel, straight arms jointed midway between the arms. (Fig. 32.)	23·801	0·516	1·147	0·6262	AB	0·416	1·432	0·5584	3·205	2·20	23·87
					BC	0·414	1·415	0·5492			
					CD	0·410	1·434	0·5428			
					DA	0·410	1·415	0·5428			
Four armed wheel, straight arms jointed along the arms. (Fig. 33.)	23·822	0·546	1·148	0·6268	AB	0·440	1·527	0·6323	3·12	3·02	23·75
					BC	0·426	1·456	0·5812			
					CD	0·426	1·521	0·6055			
					DA	0·435	1·475	0·6010			

The jointed wheels were cast in two halves, and were united by a simple flanged joint consisting of two rather heavy rectangular lugs cast on the inside of the rim with a single $\frac{3}{8}$ inch bolt passing through them. The two halves of the boss were also united by rectangular flanges, two $\frac{3}{8}$ inch bolts passing through each pair of flanges at a distance of 1·8 inches from the centre of the wheel, This joint was made of the simplest possible construction in order to simplify any calculations that may be made. Each casting was very carefully set up on the planing machine and the face of junction planed truly level and to the desired dimensions. The bolt holes were then drilled to such a size that the bolts had to be lightly hammered in, by this means any slackness in the joint was obviated.

Table of Dimensions of Rim Joint.

Wheel.	Position of joint.	Radial breadth of flange (mean inches.)	Circum. length of two lugs in inches.	Depth in inches.	Dist. of bolt from inside edge.	Weight, pounds	
						Two Lugs.	Bolt.
Four armed, jointed between arms.	bay A.	1·088	1·520	1·150	0·50	0·479	0·123
	bay C.	1·100	1·490	1·150	0·50	0·482	0·123
Four armed, jointed along arms.	arm AB.	1·044	1·520	1·150	0·45	0·458	0·123
	arm CD.	1·034	1·550	1·150	0·50	0·469	0·123

In the case of the wheel jointed at the centres of the bays the diameter of the boss measured across the flanges was 4·7 inches, and the thickness of the pair of flanges was 1·95 inches. The corresponding measurements for the wheel jointed along the arms were 4·8 and 1·91 inches.

Weights of rotating parts :—

Spindle	7·66 lbs.
Pulley, key, and collar	5·25 ,,
Cross-bar and set-screws	2·16 ,,
Shackles with nuts each...	0·16 ,,
Total	15·23 lbs.

The physical properties of the material of the wheels were carefully determined, test pieces being cast at the same time as the wheels. The casts were made of ordinary engine casting metal, about half a ton of which was taken from the cupola and casts made in the following order:—

1. Tensile test piece.
2. Wheel with six arms.
3. Cross-breaking bar.
4. Wheel with three arms.
5. Tensile test piece.

A second set was then cast. The castings were left in the sand till they were quite cold.

The specific gravity of the material was determined by means of a chemical balance, the mean of several determinations being 7·156. Tensile tests were made on a Greenwood and Batley horizontal testing machine of 100,000 pounds capacity, the extensions being measured by means of Martens' mirror apparatus on a length of eight inches. The results are given in the following table:—

Tensile Tests.

Specimen for Wheel.	Diameter inches.	Area sq. inches.	Extension per 100 lbs. 0·0001 mm.	Modulus of Elasticity lbs. per square inch.	Breaking Load.	
					Total lbs.	Per square inch.
Three armed ...	0·799	0·5022	30	13,300,000	12,375	24,640
Four armed straight and curved arms.	0·622	0·3028	48·9	13,400,000	7,750	25,590
Six armed	0·691	0·3736	37·5	14,200,000	9,700	25,960
Four armed, jointed between arms.	0·630	0·3117	45·5	13,736,000	8,200	26,307
Four armed, jointed along arms.	0·620	0·3019	49·0	14,327,000	7,770	25,737

The test pieces for the cross-breaking tests were carefully planed on all four faces until their breadth and depth were approximately the same as those of the rims of the wheels. The tests were carried out on a Ewing apparatus for transverse tests, the beam being supported on its small face on knife-edges. The load was applied at the centre

of the beam by means of a hanger on which were placed known weights. The deflections at the centre were read directly by means of a microscope with a scale in the eye-piece, of which one division equals 0·00127 inches. The modulus of elasticity is found from the formula

$$E=\frac{Wa^3}{6\,\omega I}$$

where W = central load.
a = half span.
ω = deflection.
I = moment of inertia.

The beam was also fixed (encastré) at each end and loaded, the deflections being taken as before.

The modulus of elasticity in this case is calculated by the formula

$$E=\frac{WL^3}{192\,\omega I}$$

where L = span. ω = deflection as before.

The beam was then tested to destruction by placing it on knife edges 30 inches apart and loading at centre. The results of these tests are given in the following table:—

Transverse Tests.

Specimen for Wheel.	Span inches. [1] Knife edges. [2] encastre	Breadth in inches.	Depth in inches.	Deflection per lb. ·00127 ins. on knife-edges.	Modulus of Elasticity lbs. per sq. inch on knife edges.	Deflection per lb. ·00127 ins. encastre.	Modulus of Elasticity lbs. per square inch. encastre.	Modulus of rupture lbs per sq. inch.
Three armed	[1]30·00 [2]27·00	0·996	0·536	2·14	15,846,000	0·492	12,906,000	38,080
Four armed, straight and curved.	[1]36·25 [2]28·5	0·925	0·536	4·45	15,044,000	0·558	13,825,000	...
Four armed, jointed.	[1]23·6 [2]23·6	0·942	0·500	1·42	15,630,000	0·815	12,200,000	38,800

For the six armed wheel the cross breaking test-piece was too badly flawed to be of any value, but use may be made of the values for the specimen for the three armed wheel.

The wheel was driven from a jack-shaft by means of a plaited leather belt which passed round the pulley on

the spindle. This jack-shaft was driven by belting from a series of three larger shafts, the last of which was driven by a leather belt from a 6 HP. gas engine. Thus the effects of the variations of the speed of the gas engine were greatly minimised, and the running was found to be very uniform. By gearing up from each shaft the speed obtainable was about 1,500 revolutions per minute. For the purpose of this investigation, about 1,000 revolutions per minute were considered sufficient. The belt driving the jack-shaft was allowed to have a considerable amount of slip on its pulley, the surface of this pulley being occasionally sprinkled with kerosene. By this method the speed was raised very gradually, the belt being moved very slowly from its loose pulley on the jack shaft to the driving pulley by means of a lever. The time taken to increase the speed from zero to 1,000 revolutions per minute was from four to five minutes, thus allowing ample time for a series of observations of speed and deflection to be taken.

The speed was measured by means of an electric chronograph which recorded on a sheet of smoked paper the revolutions of the wheel together with the number of vibrations made by a tuning fork of known frequency. Thus since one vibration of the tuning fork represents a definite interval of time, the time occupied by one revolution of the wheel can be ascertained by counting the number of vibrations of the fork corresponding to one revolution of the wheel. The arrangement of apparatus is shown in the diagram (fig. 8). On the spindle of the wheel is clamped a one bar commutator M, against which pressed a steel spring acting as a brush. This commutator, therefore, made and broke the current in its circuit once for each revolution of the wheel. In this circuit is a small electromagnet with a soft iron armature borne on a spring (S_3). The action of this spring is to hold the armature apart

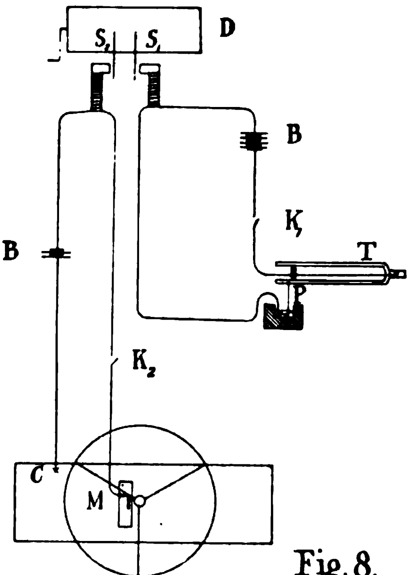


Fig. 8.

B B, battery. $K_1 K_2$, keys. T, tuning fork. P, platinum wire dipping into mercury. $S_1 S_2$, electromagnets with styluses. M, make and break. C, connection to bed-plate.

from the magnet when the circuit is open. Rigidly attached to the armature is a stiff stylus, which presses upon smoked paper wrapped round a drum capable of rotation. The axis of this drum is a screw, which is borne on a stand; when the handle of the drum is turned, the drum rotates and at the same time moves longitudinally, thus allowing a continuous record. In the other circuit is a tuning fork *T*, which makes 100 vibrations per second, as determined by comparison with a standard König fork making 50 vibrations per second, and an electromagnet with its stylus as before. The current in this circuit is made and broken by a piece of platinum wire which dips into a bath of mercury at *P*. The mercury bath must be covered by a stream of alcohol in order to keep it clean. Between the arms of the

fork is a small electromagnet which is included in the same circuit. This causes the fork to work automatically once it is set in vibration. Keys are inserted in each circuit as shown. Each vibration of the fork corresponds to one hundredth of a second. Thus by counting the number of these corresponding to the interval between the points of making or of breaking of the wheel circuit, the time of one revolution may be found. For greater accuracy several such series may be counted and the average taken. By this means the speed at any instant can be obtained easily within one per cent.

In making a test, the distance rod was first fixed in the desired position on the rim of the wheel. The points of the rod were set into two small chisel grooves, and a rubber band was slipped round this end of the rod in order to hold the points firmly in position. The holding down bands were then slipped round the rod and the cross-bar. The mirror was then moved about until the knife edge was visible in the telescope, and the zero reading taken. The driving belt was gradually pushed over, and the spindle and fork circuits closed, the fork being set in vibration. The observer then watched the movement of the knife edge on the micrometer scale, and, when he desired to take a reading of the deflection at any instant, he rotated the drum through about a third of a revolution, at the same time noting the reading on the scale. By this means the deflection and speed were observed at approximately the same instant. The curves traced on the smoked paper were fixed by dipping it into a trough containing a solution of shellac in alcohol, and allowing it to dry. These cards were then worked up and the deflections plotted against speeds, for each particular position. From these curves, the true shape of the rim at any speed is obtained by plotting the deflection at that speed against angular

distance from the arms. In every case allowance is made for the extension of the distance rod, so that actual deflections are plotted.

The curves in fig. 9 represent a comparison of the extensions of an arm of each of three wheels at various speeds, both the observed and calculated extensions being given. The wheels represented are the three- four- and six-armed wheels with straight arms and without joints. The extensions are calculated according to Professor Lanza's[1] theory, whose expression for the extension of the arm is

$$\Delta R = \frac{R}{E}\left\{\frac{G}{g}\nu^2 - \frac{F}{2\alpha A}\right\}$$

where $F = \frac{1}{3}\frac{G}{g}\nu^2 K.$

$$\text{and } K = \frac{3 - \left(\frac{r_1 - r_2}{R}\right)^2\left(\frac{r_1 + \frac{1}{2}r_2}{R}\right)}{\frac{1}{A_1}\cdot\frac{(r_1 - r_2)}{R} + \frac{1}{2A\alpha}}.$$

In these equations ΔR = extension of the arm due to centrifugal effect of the rim and of the arm itself (in feet).

R = distance from centre of hub to centre of rim in feet.

α = one half the angle between two consecutive arms.

ν = linear velocity in feet per second of centre of rim.

A = area in square feet of cross section of rim.

G = weight of the metal in pounds per cubic foot.

g = 32·16 feet per second per second.

F = pull in pounds exerted by each arm on the rim so that shearing force in the rim close to the arm = $F/2$.

r_1 = distance in feet from centre of hub to outer end of arm.

r_2 = radius of hub in feet.

E = modulus of elasticity of cast iron in pounds per square foot.

A_1 = area of cross section of arm in square feet when the arm is of uniform section throughout.

[1] Lanza, Trans. Am. Soc. Mech. Engs., Vol. XVI., p. 208.

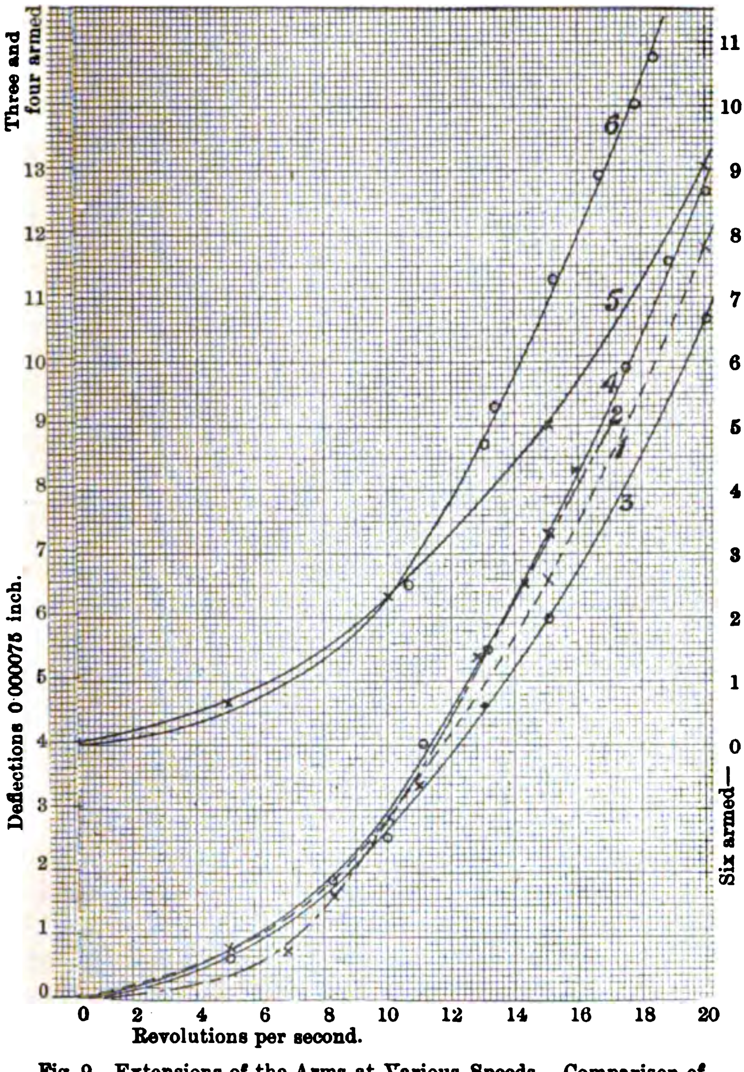


Fig. 9—Extensions of the Arms at Various Speeds.—Comparison of Calculated and Experimental Values.

No. 1. Three armed wheel, calculated extension of arm AB.
„ 2. Three armed wheel, observed extension of arm AB.
„ 3. Four armed wheel, calculated extension of arm AD.
„ 4. Four armed wheel, observed extension of arm AD.
„ 5. Six armed wheel, calculated extension of arm AF.
„ 6. Six armed wheel, observed extension of arm AF.

Professor Unwin has deduced a similar expression for the extension of the arm (see Elements of Machine Design, Part II.), but his value of the constant is different, viz.:—

$$K = \frac{2}{\frac{1}{A_1} + \frac{1}{2\,A\alpha}}$$

in which the letters have the same meaning as above. This difference is due to the difference in their assumptions. Each assumes the arms to be of uniform cross section for simplicity in calculation; but Professor Unwin assumes that a sufficiently close approximation will be made by considering the arms to extend from the centre of the shaft to the centre of the rim, whereas Professor Lanza assumes the arms to extend from the outer circumference of the boss to the inner circumference of the rim.

The values used in the calculations for the three wheels are given in the following table. For each case the value of $G = 445$ lbs. per cube foot. $g = 32{\cdot}16$ feet per second. $\nu = 6{\cdot}06$ feet per second for 1 revolution per second.

Wheel.	Arm.	α	r_1 feet.	r_2 feet.	R feet.	A sq. feet.	A_1 sq. feet.	E lbs per sq. ft.	K Unwin.	K Lanza.	F at 1 revol. per sec.	ΔR inch at 1 revolution per second.
Three armed wheel ...	AB	$\frac{\pi}{3}$	0·94	0·16	0·96	·00441	·00405	13,800,000 × 144	·0057	·00764	1·294	$0{\cdot}2208 \times 10^{-5}$
Four armed wheel ...	AD	$\frac{\pi}{4}$	0·94	0·12	0·97	·00437	·00415	13,400,000 × 144	·0052	·00648	1·064	$0{\cdot}2004 \times 10^{-5}$
Six armed wheel ...	AF	$\frac{\pi}{6}$	0·94	0·12	0·97	·00509	·00429	14,200,000 × 144	·0047	·0054	0·985	$0{\cdot}1689 \times 10^{-5}$

The values of F and ΔR at any speed are obtained by multiplying the above values by the square of the speed in revolutions per second.

On inspection of the curves it will be seen that the observed and calculated values lie very close together for the three-armed wheel, while they are somewhat divergent for the other two wheels, the difference being greater for the higher speeds. The curve of calculated values is a parabola, whereas the curve of observed deflections is flatter than the parabola at low speeds and steeper at higher speeds.

Three-armed Wheel, straight arms.—Fig. 10 gives a complete set of curves for one half of bay C of the three-armed wheel, points being taken 15° apart. Curves are also shewn for the centres of bays A and C and for the arm AB. The points B. 60° and arm AB shew considerable divergence from the corresponding points in bay C, a fact which cannot be accounted for by any variation in the dimensions of the wheel. The shape of the rim between the arm and centre of bay C for speeds ranging from 4 to 14 revolutions per second is shewn in fig. 11.

A series of experiments was carried out on the three-armed wheel, in which concentrated loads were applied in a radial direction to the centre of each bay while the wheel was stationary, the deflections at points 15° apart in each bay being noted as before. The load at each bay was applied by means of a loop of copper wire on the rim. This loop was pulled in a radial horizontal direction by a piece of cord attached to it. The cord passed over a pulley supported on roller bearings and was attached to a bucket in which weights were placed. In order that the deflection might be taken at each point, and at the same time to keep the load on the centre of the bay it was necessary to move the stands supporting the pulleys for each point under

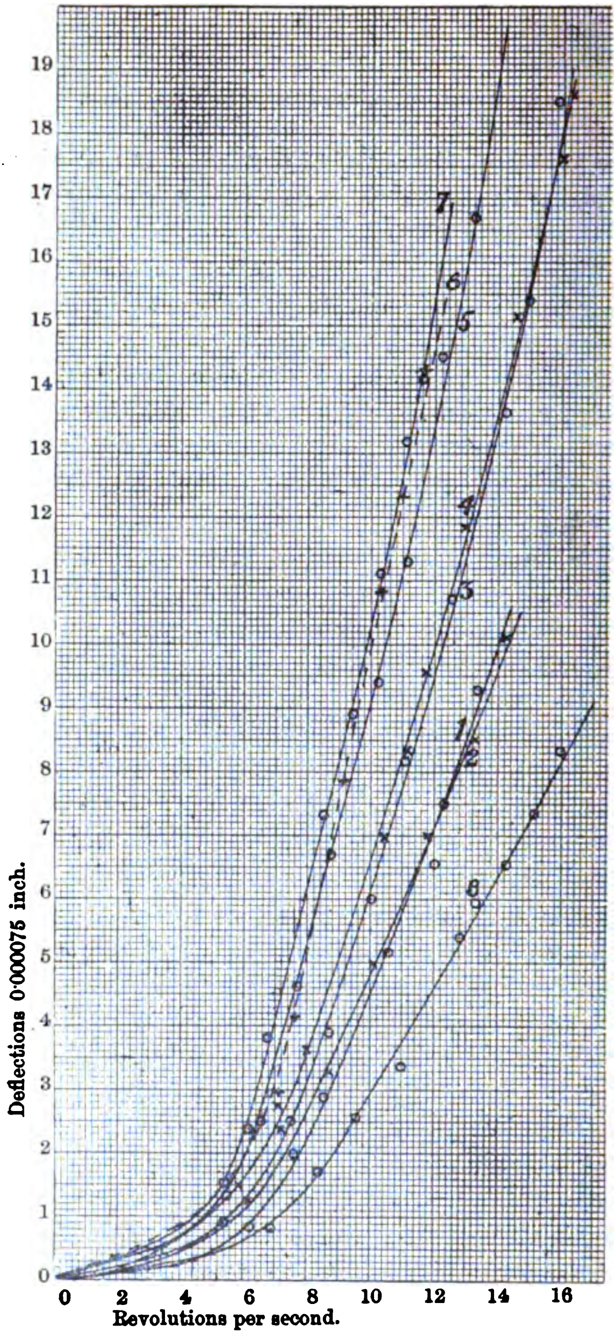


Fig. 10—Three Armed Wheel.—Curves shewing Radial Deformations at Various Positions on Rim at Rising Speeds.

No. 1. Arm AC.
" 2. Bay C 15° from arm AC.
" 3. Bay C 30° "
" 4. Bay B 60° from arm AB.
No. 5. Bay C 45° from arm AC.
" 6. Bay A 60° "
" 7. Bay C 60° "
" 8. Arm AB.

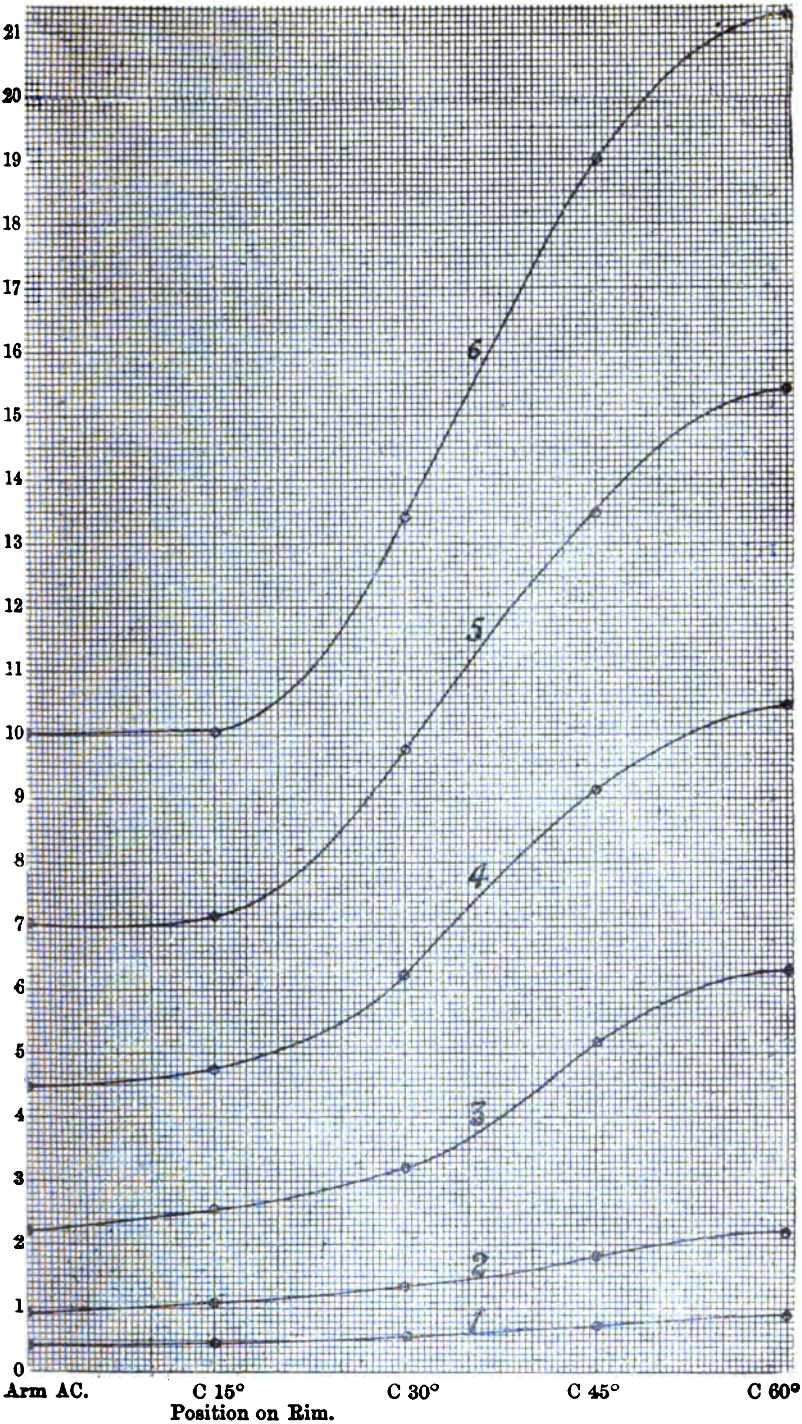


Fig. 11—Three Armed Wheel—Curves shewing Deformations of Bay C at various speeds.

No. 1. Curve of Deformation at 4 revolutions per second; No. 2, at 6; No. 3 at 8; No. 4, at 10; No. 5, at 12; No. 6, at 14 revolutions per second.

examination. The load was applied by placing equal weights in the buckets simultaneously. The deflections were plotted against loads for each position (see fig. 12), and the deflections for given loads were also plotted against positions on the rim 15° apart for one half of bay *C* (see fig. 13). The resulting curves shew that there was a large inflection in the rim near the arms.

Four-armed Wheel, straight arms.—The curves obtained for this wheel are shewn in figs. 14 to 17. Each of the four half bays was measured, a pair of opposite bays being represented in each figure. There is some variation in the deflection of the bays, that of the bays *B* and *C* being greater than the others, especially at the high speeds. The arms *AB*, *BC*, *AD* are of approximately the same extension, whereas that of arm *CD* is a little less than the others. The deflections of the 11·25° position show some peculiarity; for the deflections of *A* 11·25° and *C* 11·25° are greater than those of the corresponding arms, whereas in the case of bays *B* and *D* the deflections are equal to those of the arms or even a little less.

Four-armed Wheel, curved arms.—The results for this wheel are set forth in figs. 18 and 19. The four bays were measured, two of them being shewn in fig. 19. It will be seen that the maximum deflection is at or near the arms; there being a considerable inflection about midway between the arms. The maximum deflection obtained was at *B* 11·25°, *i.e.*, on the concave side of the arm *AB* and amounted to 64 scale divisions at 18 revolutions per second. The maximum inflection was in the same bay between 45° and 56·25° and was 22 scale divisions. Bay *C* (not shown) gave results very similar to bay *A*, the maximum deflection being at the arm *BC*, and 5% less than that of *AD* in magnitude. The results for bay *D* (not shown) were similar to those for bay *B*, the maximum deflection being at *D* 11·25°, and the

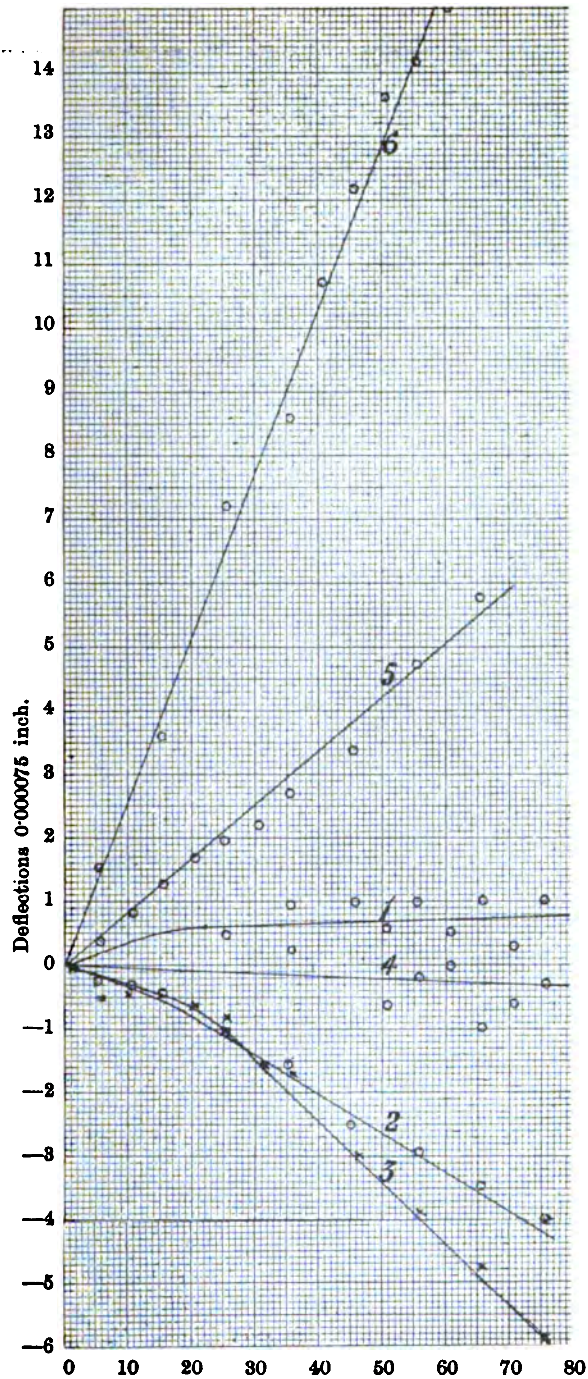


Fig. 12—Three Armed Wheel—Curves shewing Radial Deformations at various positions on Rim at various loadings at centres of the three bays. No. 1 Arm AC. No. 2, Bay C, 15° from arm AC; No. 3, 30°; No. 4, 37·5°; No. 5, 45°; No. 6, 60°.

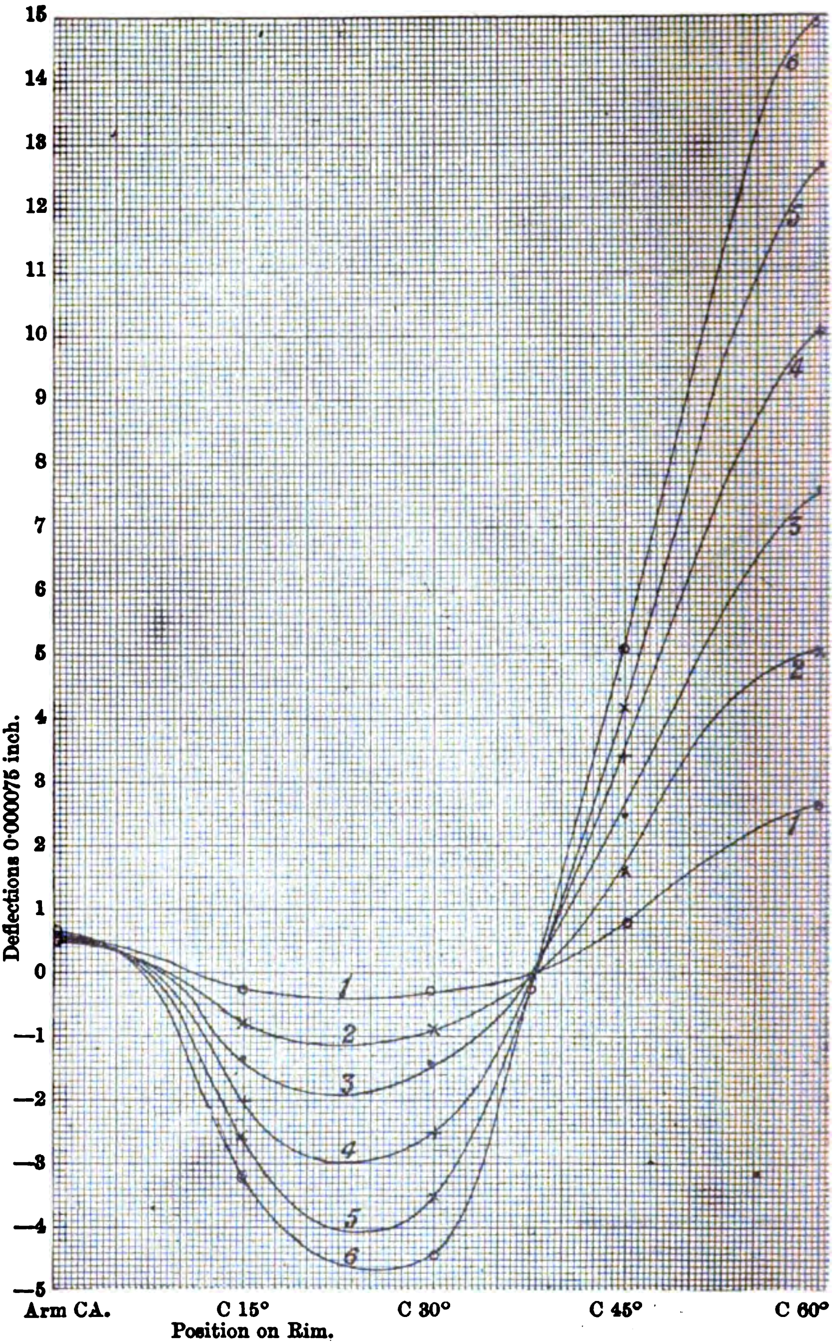


Fig. 13—Three Armed Wheel—Curves shewing Deformations of Bay C at various central loads. Wheel stationary.

No. 1. Curve of Deformation with 10 pounds pull at centre of each bay; No. 2 with 20; No. 3 with 30; No. 4 with 40; No. 5 with 50; No. 6 with 60.

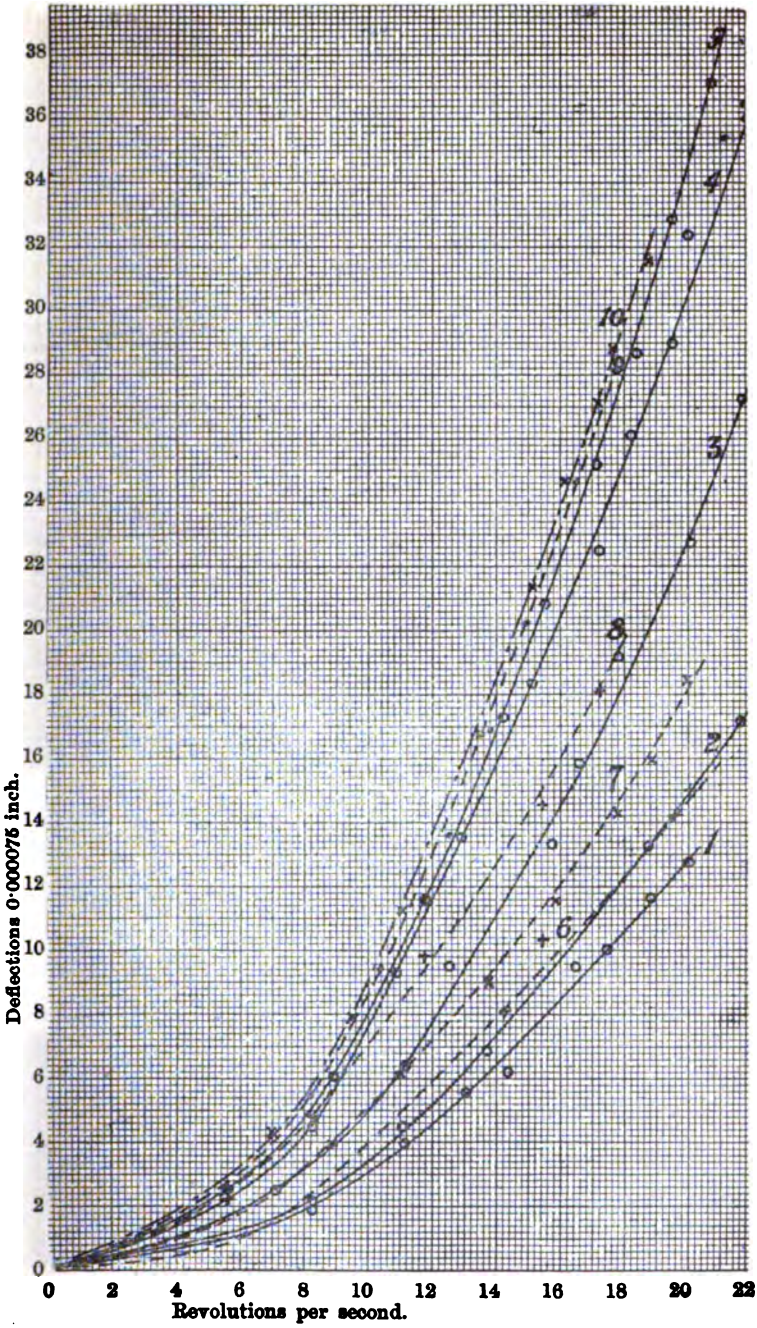


Fig. 14. Four Armed Wheel—Straight Arms. Curves shewing Radial Deformations at various positions on rim at rising speeds. Bays A and C.

No. 1. Arm AD.
No. 2. Bay A, 11·25° from arm AD;
No. 3, 22·5°; No. 4, 33·75°; No. 5, 45°.

No. 6. Arm BC.
No. 7. Bay C, 11·25° from arm BC;
No. 8, 22·5°; No. 9, 33·75°; No. 10, 45°

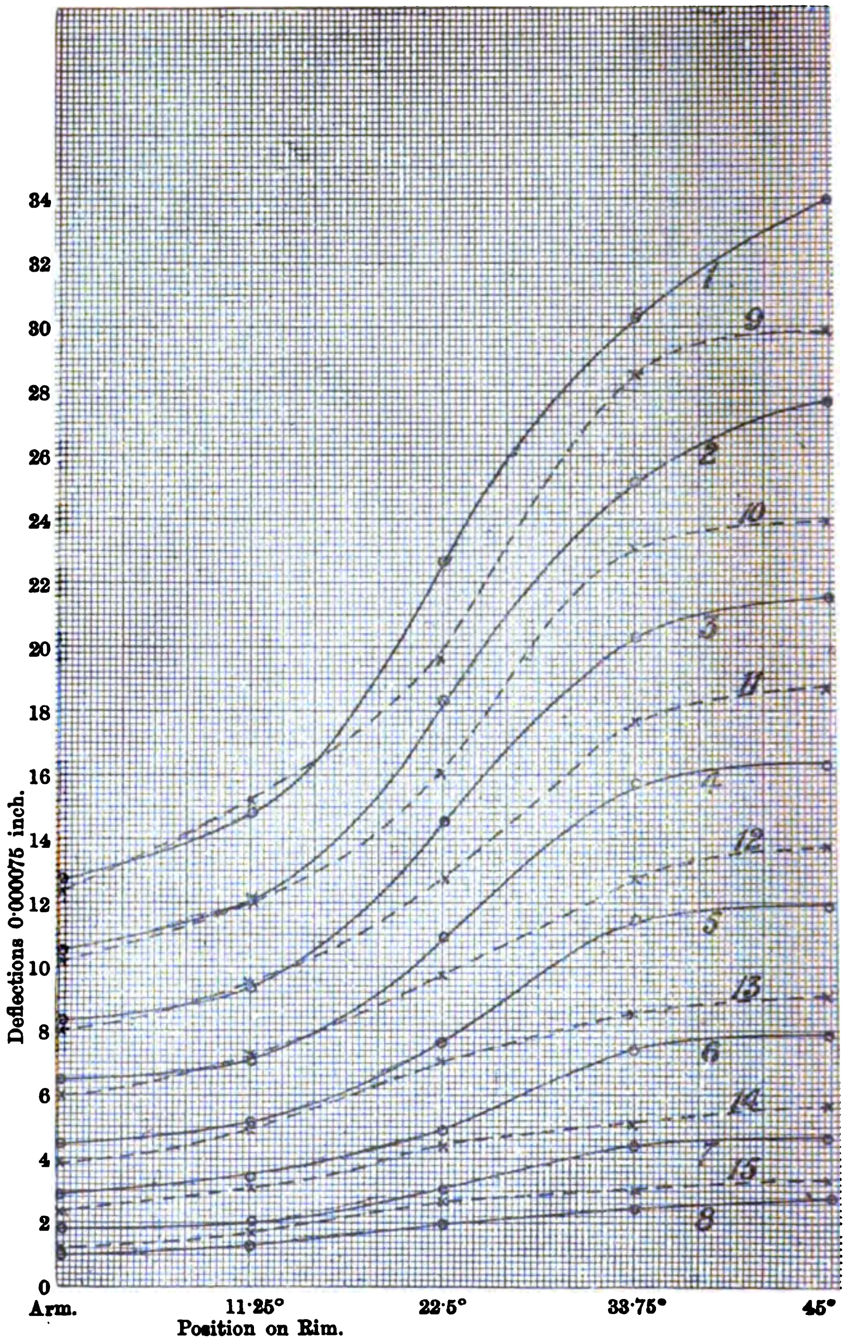


Fig. 15—Four Armed Wheel—Straight Arms. Curves shewing deformations of rim at various speeds.

No. 1, Bay A, 20 revolutions per second; No. 2, 18; No. 3, 16; No. 4, 14; No. 5, 12; No. 6, 10; No. 7, 8; No. 8, 6.

No. 9, Bay C, 18 revolutions per second; No. 10, 16; No. 11, 14; No. 12, 12; No. 13, 10; No. 14, 8; No. 15, 6.

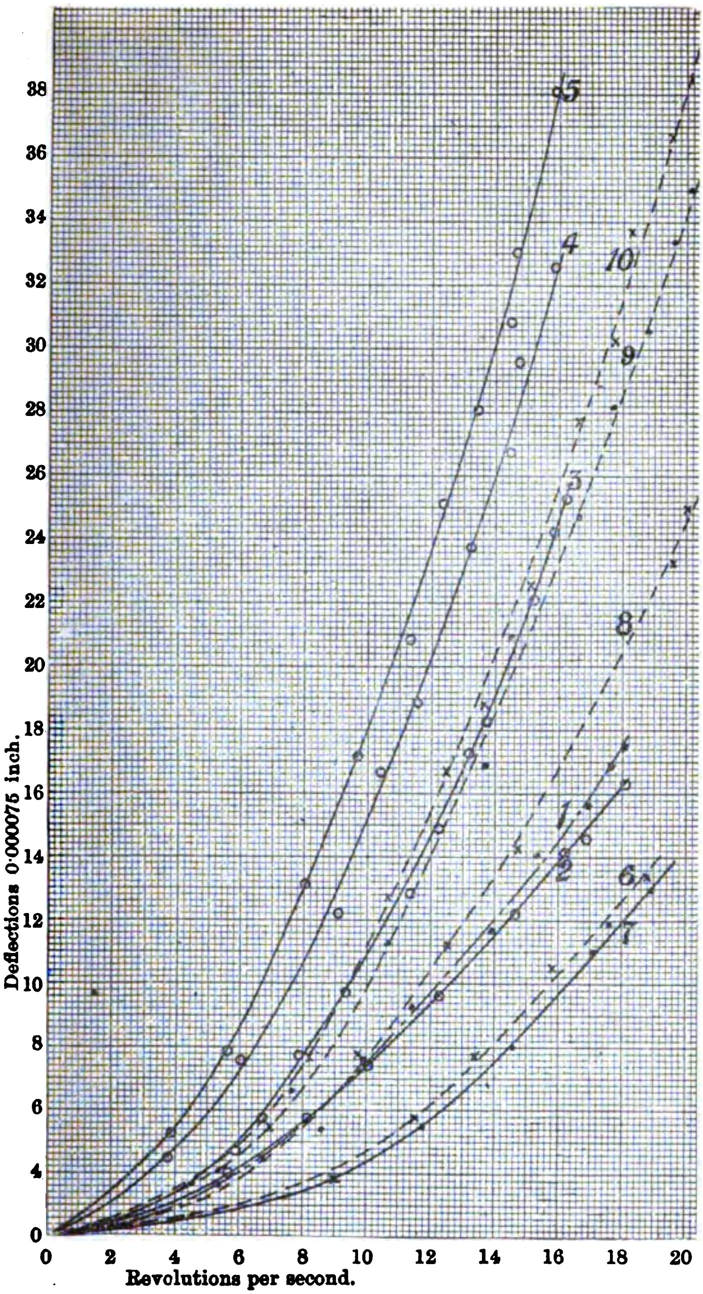


Fig. 16—Four Armed Wheel—Straight Arms. Curves shewing Radial Deformations at various positions on rim at rising speeds. Bays B and D.

No. 1. Arm AB.
No. 2, Bay B, 11·25° from arm AB;
No. 3, 22·5°; No. 4, 33·75°; No. 5, 45°

No. 6, Arm CD.
No. 7, Bay D, 11·25° from arm CD;
No. 8, 22·5°; No. 9, 33·75°; No. 10, 45°

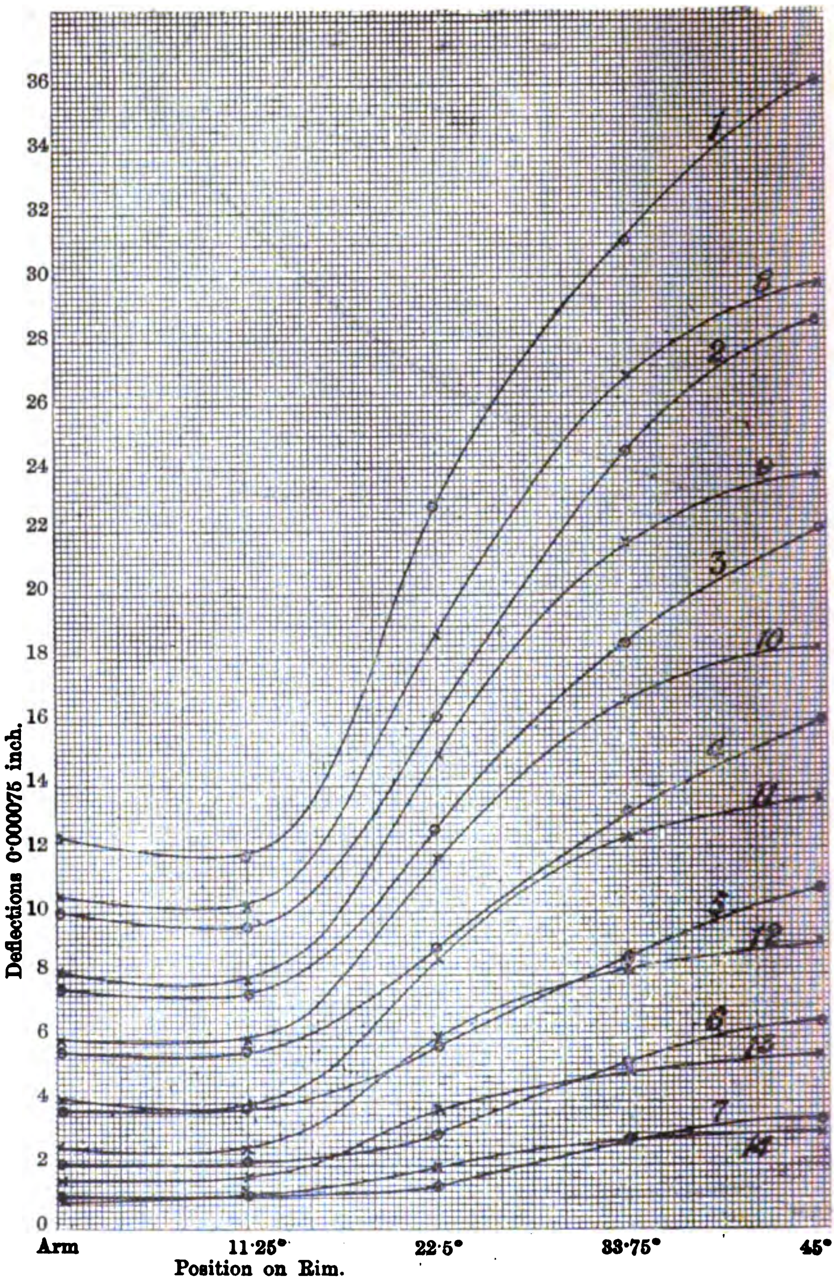


Fig. 17—Four Armed Wheel—Straight Arms. Curves shewing deformations of rim at various speeds.

No. 1, Bay B, 18 revolutions per second; No. 2, 16; No. 3, 14; No. 4, 12; No. 5, 10; No. 6, 8; No. 7, 6.

No. 8, Bay D, 18 revolutions per second; No. 9, 16; No. 10, 14; No. 11, 12; No. 12, 10; No. 13, 8; No. 14, 6.

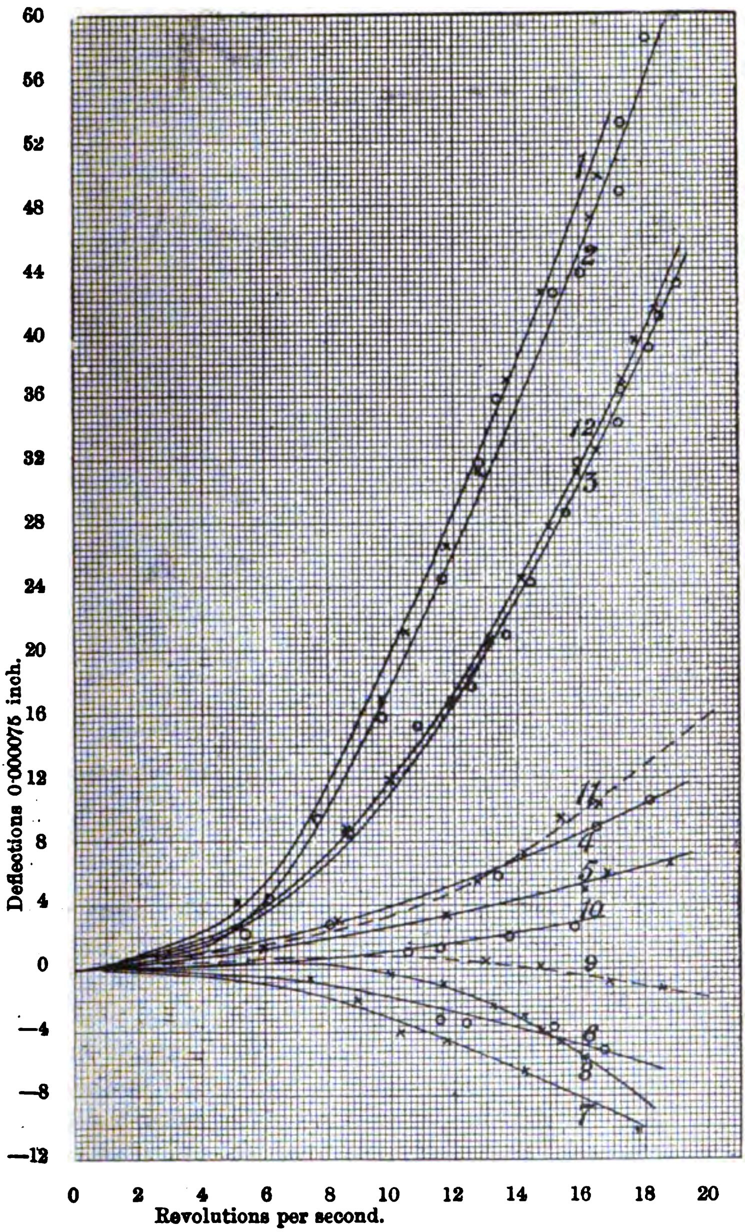


Fig. 18—Four Armed Wheel—Curved Arms. Curves shewing radial deformations at various positions on rim at rising speeds.

No. 1. Arm AD.
No. 2, Bay A, 11·25° from arm AD; No. 3, 22·5°; No. 4, 33·75°; No. 5, 36·56°; No. 6, 39·37°.
No. 7, Bay A, 45° from arm AD; No. 8, 56·25°; No. 9, 61·87°; No. 10, 64·68°; No. 11, 67·5°; No. 12, 78·75°

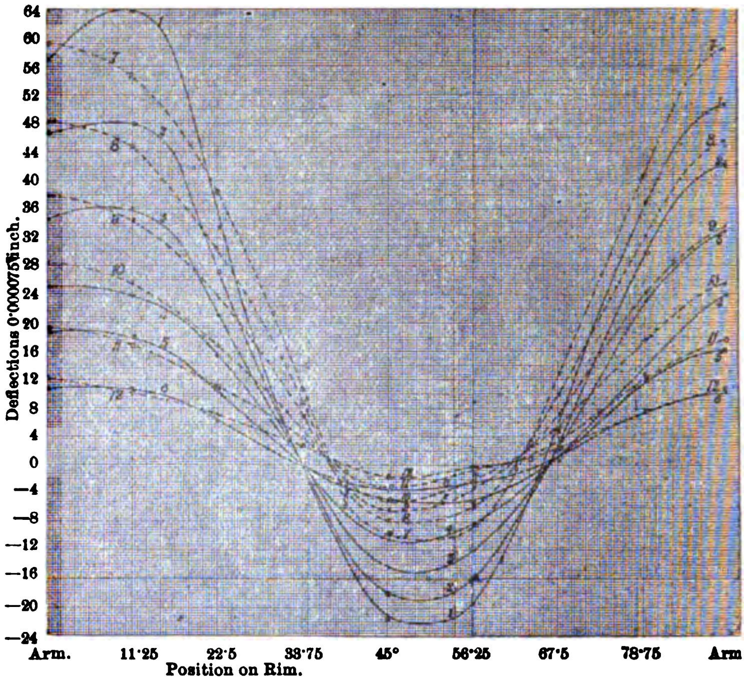


Fig. 19—Four Armed Wheel—Curved Arms. Curves shewing deformation of Bays at various speeds.

No. 1.	Bay B,	18 revolutions per second	No. 7.	Bay A,	18 revolutions per second
„ 2.	„	16 „ „	„ 8.	„	16 „ „
„ 3.	„	14 „ „	„ 9.	„	14 „ „
„ 4.	„	12 „ „	„ 10.	„	12 „ „
„ 5.	„	10 „ „	„ 11.	„	10 „ „
„ 6.	„	8 „ „	„ 12.	„	8 „ „

deflections being 6% less in magnitude. The arms were designed as regards their curvature according to Unwin's "Machine Design," part 1, p. 397. The section of the arms was uniform throughout for simplicity, and was approximately the same as that of the straight armed wheels. They of course tend to straighten as the rim expands and are therefore subjected to cross breaking. The arms are much stiffer relatively to the rim than would be the case in practice, and therefore cause much more relative bending of the rim.

Six-armed Wheel, straight arms.—Curves for the six-armed wheel are represented in figs. 20 and 21. Only those

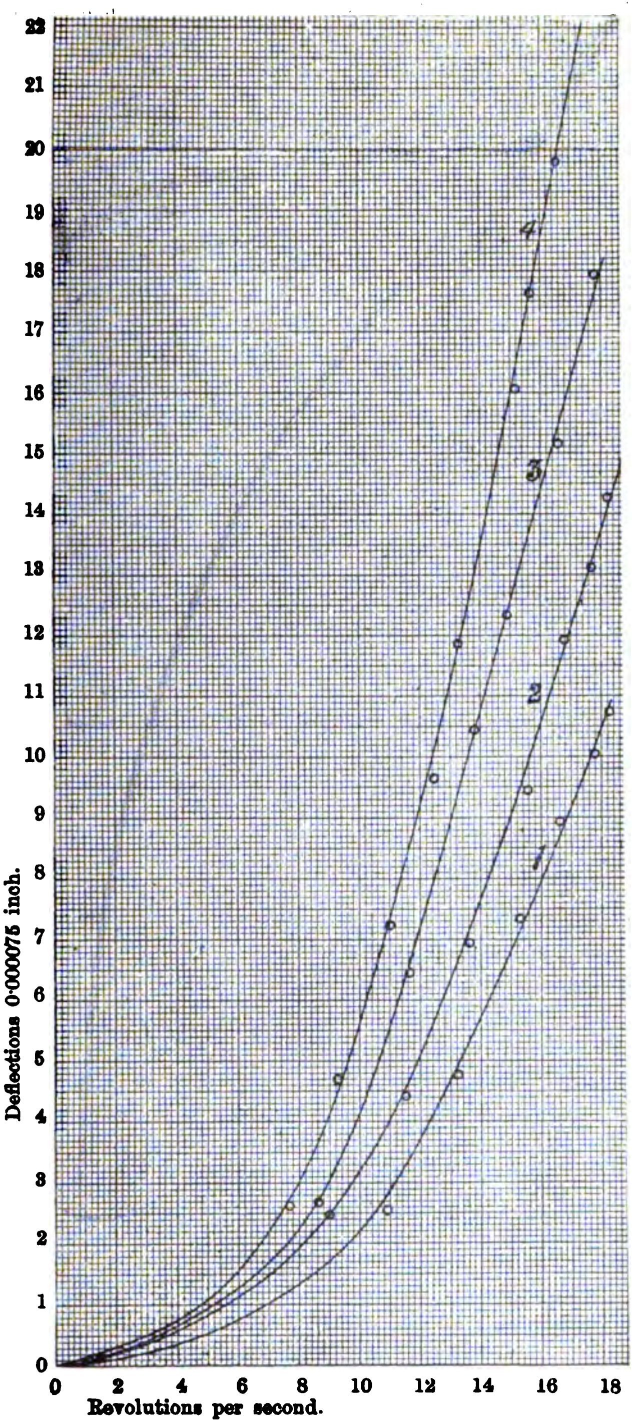


Fig. 20—Six Armed Wheel—Curves shewing Radial Deformations at various Positions on Rim at Rising Speeds.

No. 1, Arm AF. No. 2, Bay F, 15° from AF. No. 3, Bay F, 22·5° from AF. No. 4, Bay F, 30° from AF.

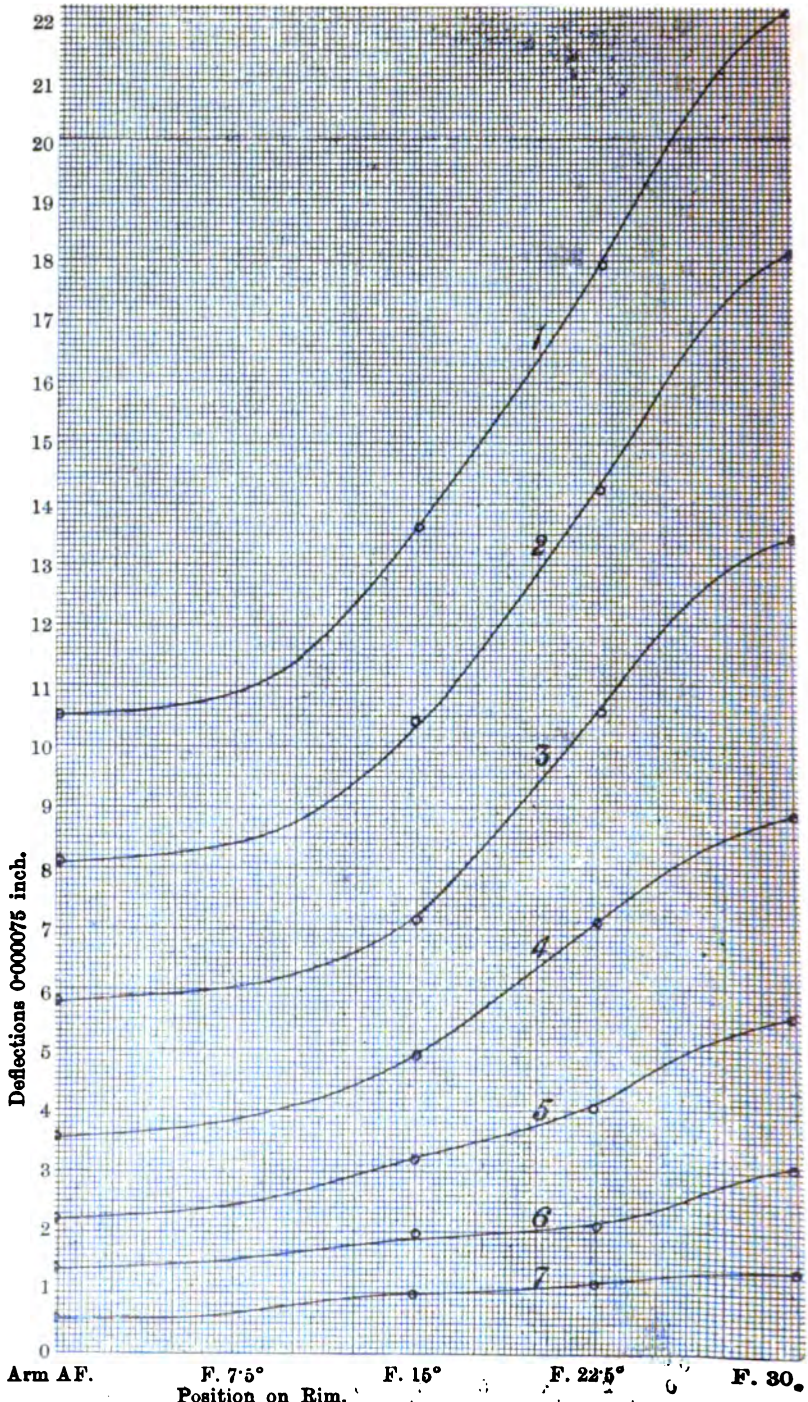


Fig. 21—Six Armed Wheel. Curves shewing deformations of Bay F at various speeds.

No. 1, Curve of deformation at 18 revolutions per second; No. 2, 16; No. 3, 14; No. 4, 12; No. 5, 10; No. 6, 8; No. 7, 6.

for bay *F* are shewn, the other bays not having been finished through press of time. This bay may be taken as representative, for trials of the centres of the other bays gave results similar to those shewn.

Four-armed Wheel, straight arms, jointed midway between the arms.—The lower set of curves in fig. 22 shews the deflections at various speeds, of points in the bays *A* and *C*, which contain the joint. The upper set of curves in fig. 23 shews the inflections at various speeds of points in the bays *B* and *D*, which do not contain the joint. It will be observed that the deflections in the jointed bays were very large, being caused both by the weakness of the joint and by the concentrated loading of the lugs. In order to separate these two effects, blocks of cast iron approximately equal to the weights of the flanges were bound by means of copper wire on the inside of the rim at the centres of bays *B* and *D*, and deflections taken as before. The deflections for bay *C* are shewn in the lower set of curves in fig. 23, and the inflections for bay *B* in the upper set on fig. 22. It will be observed that the deflections are lessened enormously, but are still very great—about four times as great as in the unjointed wheel. The inflection is also very much lessened. These effects will be seen clearly in fig. 24.

Four-armed Wheel, straight arms, jointed along the arms.—The two opposite bays *A* and *C* were completely measured (see figs. 25 to 27). The joint lay along the arms *AB* and *CD*, so that the curves in fig. 25 represent the deflections of points adjacent to the jointed arms, and the curves in fig. 26 represent the deflections of points adjacent to the unjointed arms. From fig. 27 it will be seen that in both bays *A* and *C*, the deflection of the 78·75° position was less than that of the jointed arm, there being even a considerable inflection in bay *A*. The points on the

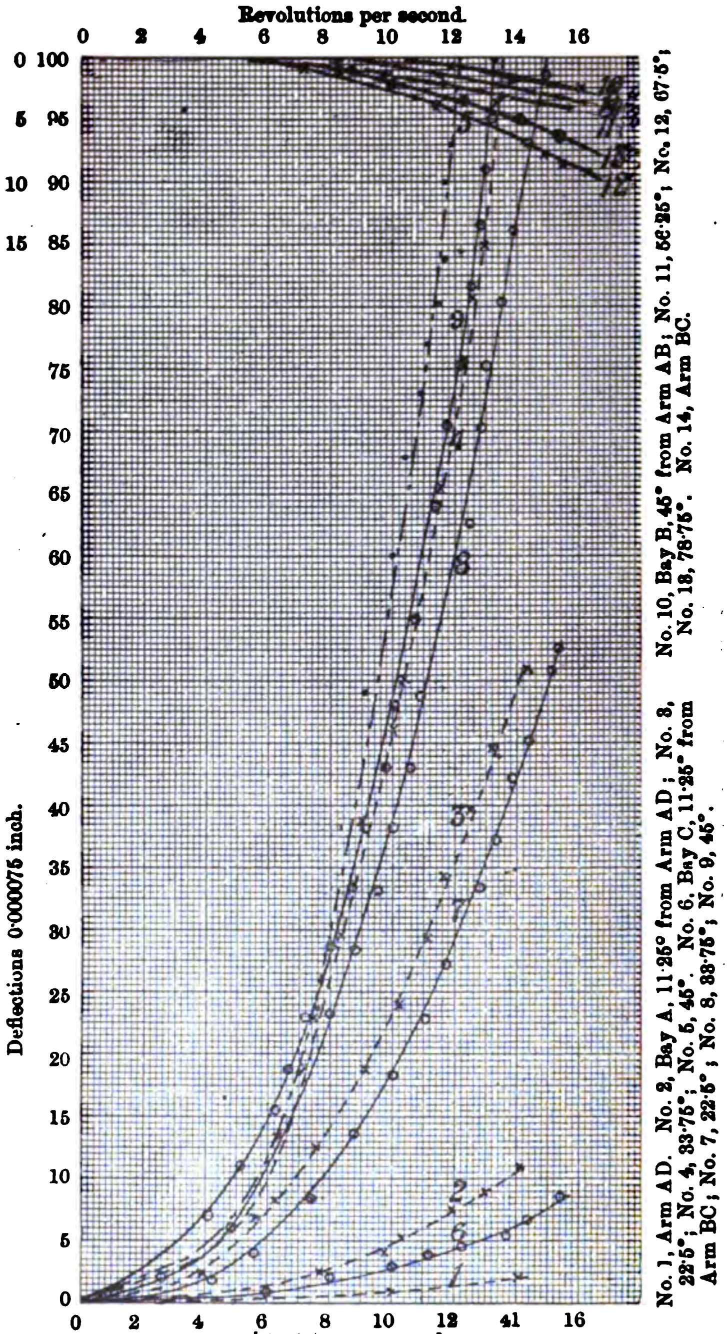


Fig. 22—Four Armed Wheel—Jointed midway between the arms. Curves shewing radial deformations of bays A and C (containing joint), and of bay B (not containing joint), the wheel being loaded in the last case.

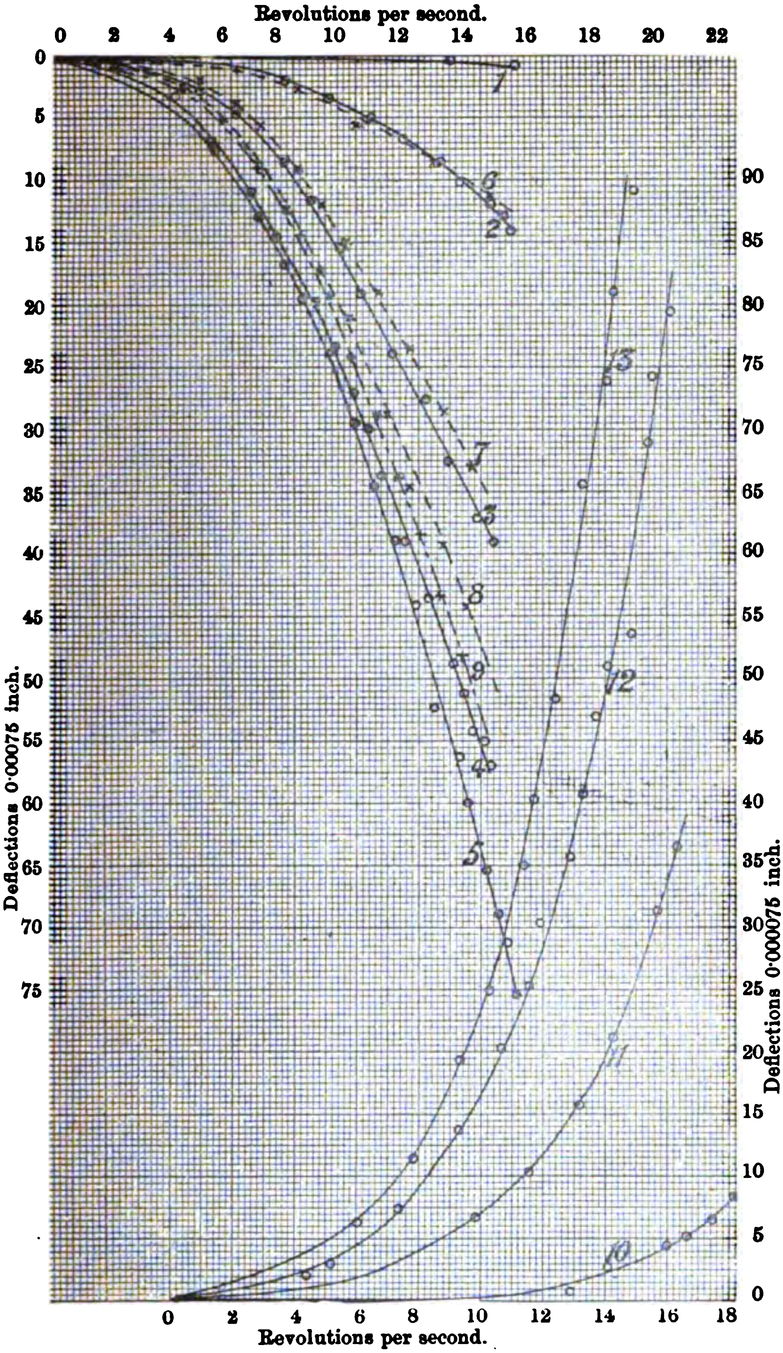


Fig. 23—Four-armed Wheel, jointed midway between the arms. Curves shewing Radial Deformations of bays B and D (not containing joint) and of bay C (containing joint), the wheel being loaded in the last case.
No. 1. Arm BC. No. 2, Bay B, 78·75° from Arm AB; No. 3, 67·5°; No. 4, 56·25°; No. 5, 45°. No. 6, Bay D, 78·75° from Arm CD; No. 7, 67·5°; No. 8, 56·25°; No. 9, 45°. No. 10, Bay C, 11·25° from Arm AC; No. 11, 22·5°; No. 12, 33·75°; No. 13, 45°.

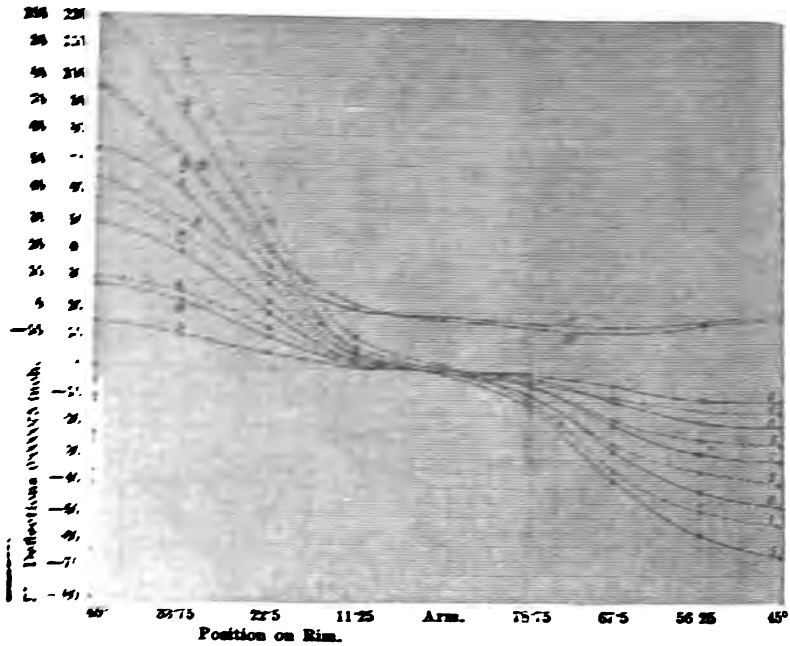


Fig. 24—Four Armed Wheel, jointed midway between the arms. Curves shewing Deformations of Rim for a distance of 45° on each side of arms AD and CB; also for bays C and B when wheel is loaded.

No. 1,	Bays A and D,	Curve	of Deformation	at 14	revolutions	per second.	
„ 2,	„	„	„	12	„	„	
„ 3,	„	„	„	10	„	„	
„ 4,	„	„	„	8	„	„	
„ 5,	Bays C and B;	„	„	14	„	„	
„ 6,	„	„	„	12	„	„	
„ 7,	„	„	„	10	„	„	
„ 8,	„	„	„	8	„	„	
„ 9,	„	„	„	6	„	„	
„ 10,	„	„	„	14	„	„	(loaded).
„ 11,	„	„	„	12	„	„	(loaded .

other side of the jointed arm *AB*, viz. *B* 11·25° and B 22·5° were also tried and gave similar results. The unjointed arm *AD* also gave an unexpected inflection at higher speeds. This must be due to the fact that this arm was slightly bent out of the plane of the wheel, and on straightening,

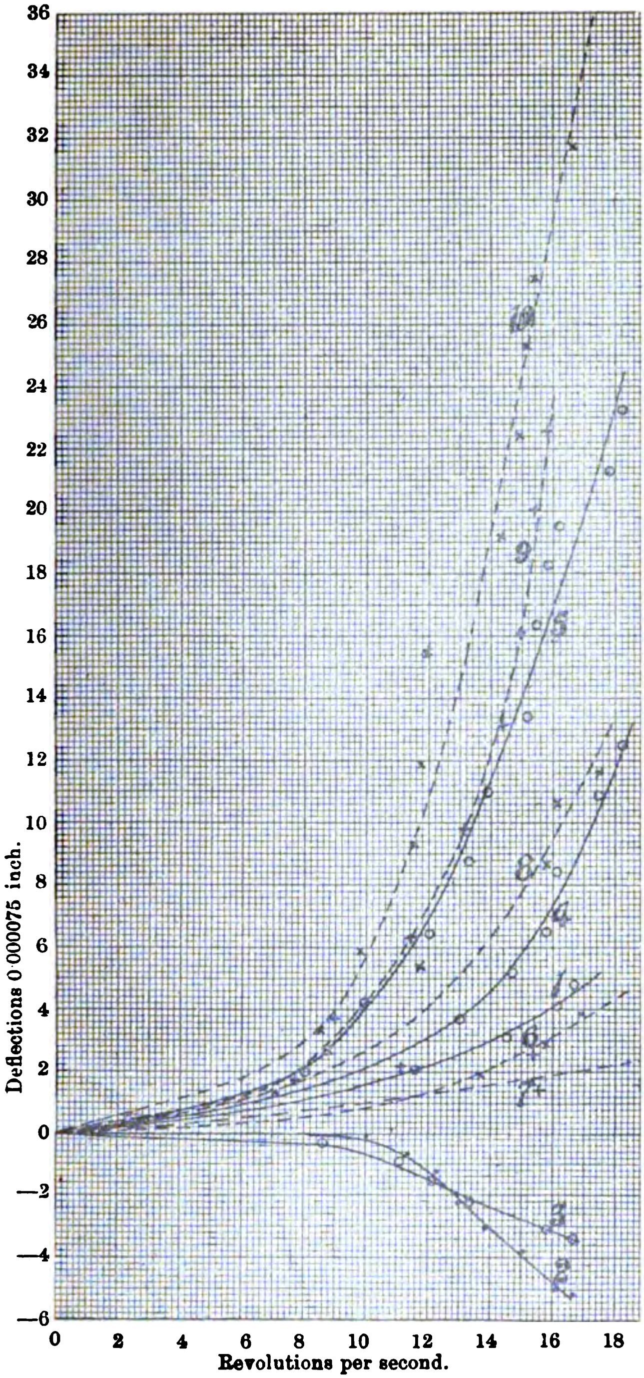


Fig. 25—Four Armed Wheel, jointed along the arms. Curves shewing radial deformations at various positions on rim at rising speeds.

No. 1, Arm AB. No. 2, Bay A, 78 85° from Arm AD; No. 3, 67·5°; No. 4, 56·25°; No. 5, 45°. No. 6, Arm CD. No. 7, Bay C, 78·75° from Arm BC; No. 8, 67·5°; No. 9, 56·25°; No. 10, 45°.

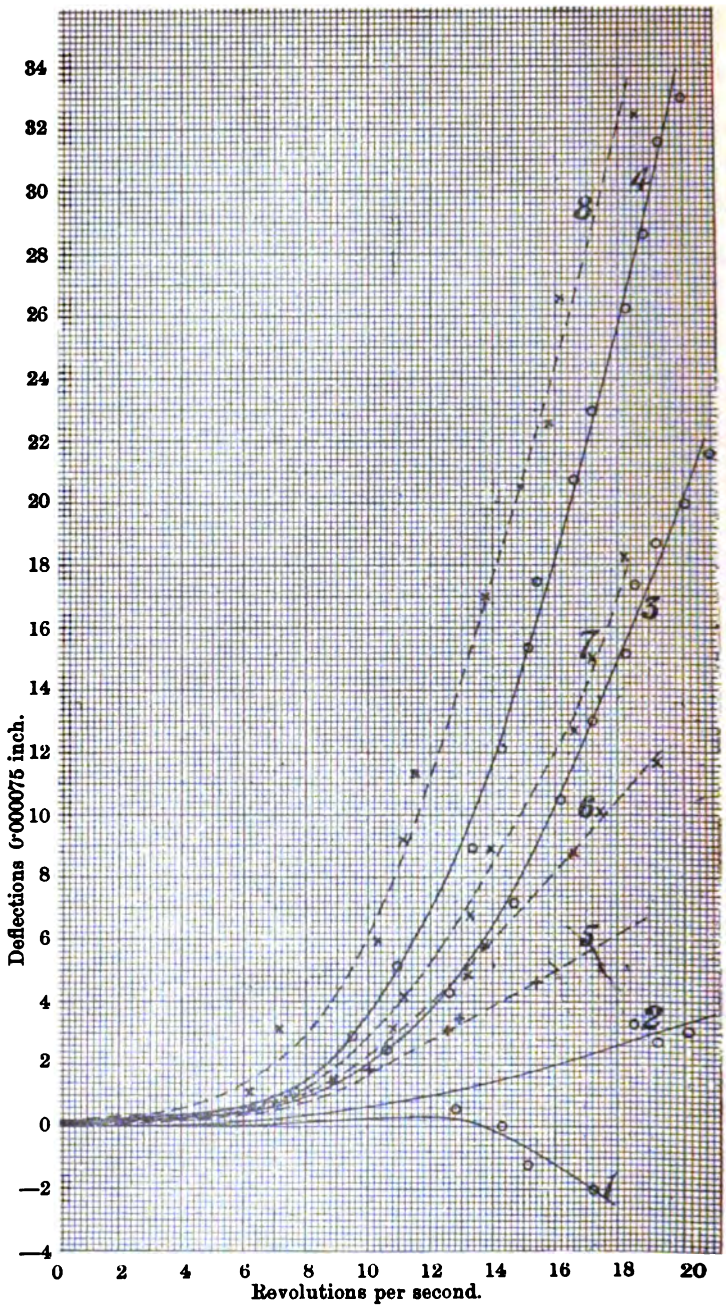


Fig. 26—Four Arm Wheel, jointed along the arms. Curves shewing radial deformations at various positions on rim at rising speeds.

No. 1, Arm AD. No. 2, Bay A, 11·25° from Arm AD; No. 3, 22·5°; No. 4, 33·75°. No. 5, Arm BC. No. 6, Bay C, 11·25° from Arm BC; No. 7, 22·5°; No. 8, 33·75°.

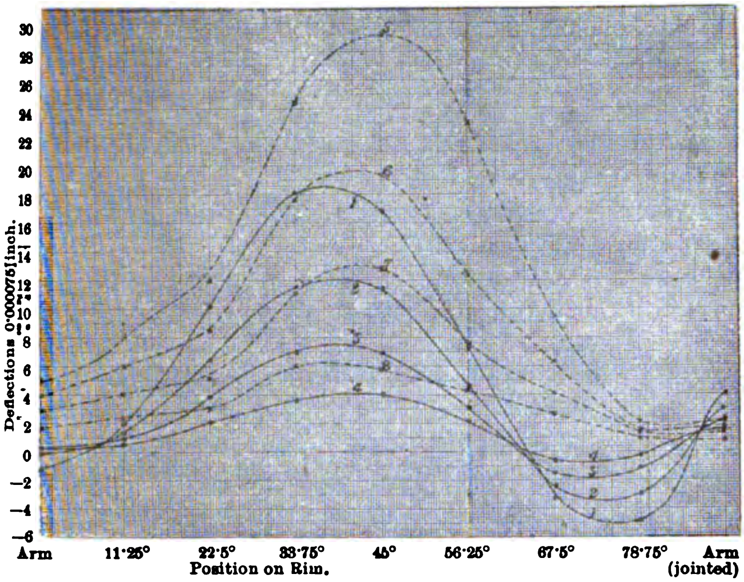


Fig. 27—Four Armed Wheel, jointed along the arms. Curves shewing deformations of Bays A and C at various speeds.

No. 1,	Bay A,	16	revolutions	per sec.	No. 5,	Bay C,	16	revolutions	per sec.
„ 2,	„	14	„	„	„ 6,	„	14	„	„
„ 3,	„	12	„	„	„ 7,	„	12	„	„
„ 4,	„	10	„	„	„ 8,	„	10	„	„

caused this inflection. The castings of this wheel were very much twisted before they were machined, so that this may be the cause of the peculiar results obtained from bay *A*. The deflections of bay *C* are very similar to those of the unjointed four-armed wheel, the joint apparently not weakening the wheel as far as its radial deformations are concerned.

In figs. 28 to 33 is given a summary of the manner of deformation for each of the six wheels at a speed of 14 revolutions per second. These shew at a glance the relative deformation of the wheels of different numbers of arms and the effect of curved arms and flanged joints.

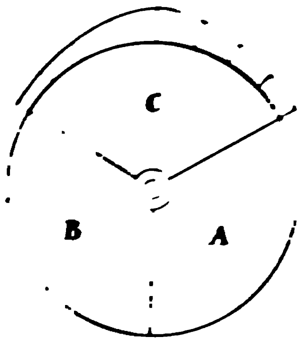


Fig 28.

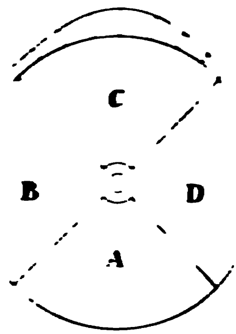


Fig 29

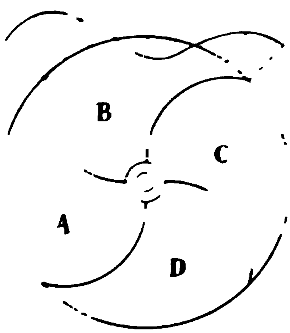


Fig 30

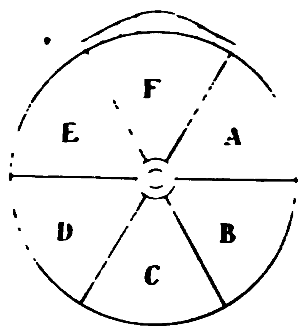


Fig. 31.

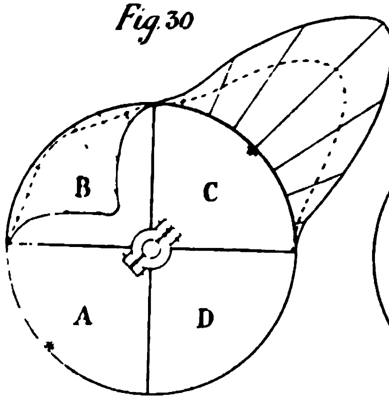


Fig. 32.

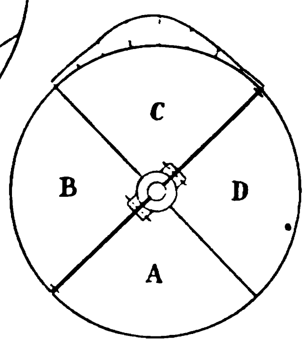


Fig. 33.

The equation to the curve of the rim may be obtained by applying Fourier's theorem[1] for the analysis of a complex single-valued periodic curve into its constituents.

In the case of the flywheels under consideration, the periodic portion lies between two arms; and is repeated for each bay if we consider the deformations the same in each bay. Since the curve between two arms corresponds to one whole period, then we may call this 360°. The curve is divided into 24 parts (say) each equal to 15°.

Let $y=$ the ordinate at any point. The values of y corresponding to each of these divisions is found from the accompanying curves. A table is formed in which are columns giving the positions on the curve (1 to 24 in present case) and the corresponding values of y, x (angle) $\sin x$, $y \times \sin x$, $\cos x$, $y \times \cos x$, $\sin 2x$, $y \times \sin 2x$ etc.

Then we have

$$
\begin{aligned}
y = A_0 + B_0 &+ \sqrt{A_1^2 + B_1^2}\,\sin(x + \theta) \\
&+ \sqrt{A_2^2 + B_2^2}\,\sin(2x + \theta') \\
&+ \text{etc.}
\end{aligned}
$$

where

$$
\begin{aligned}
A_0 + B_0 &= \text{mean of all the 24 numbers under } y \text{ column} \\
A_1 &= \text{twice mean of ,, ,, } y \times \sin x \text{ ,,} \\
B_1 &= \text{ ,, ,, ,, } y \times \cos x \text{ ,,} \\
A_2 &= \text{ ,, ,, ,, } y \times \sin 2x \text{ ,,} \\
B_2 &= \text{ ,, ,, ,, } y \times \cos 2x \text{ ,,}
\end{aligned}
$$

$$
\tan\theta = \frac{B_1}{A_1}, \quad \tan\theta' = \frac{B_2}{A_2}
$$

On testing the equations derived, it will be found unnecessary to proceed to any higher degree of complexity than that shewn. The data used in the derivation of the equations are given in the following table :—

[1] Fleming's Alternate Current Transformer, p. 87.

Position	x	cos x	cos $2x$	Three Armed Wheel.			Four Armed Wheel.			Six Armed Wheel.		
				y	$y \times \cos x$	$y \times \cos 2x$	y	$y \times \cos x$	$y \times \cos 2x$	y	$y \times \cos x$	$y \times \cos 2x$
1	0	1·000	1·000	10·00	10·000	10·000	7·00	7·000	7·000	5·80	5·800	5·800
2	15	0·966	0·866	10·05	9·708	8·703	7·20	6·955	6·335	5·85	5·651	5·066
3	30	0·866	0·500	10·07	8·721	5·035	7·25	6·378	3·625	5·92	5·127	2·960
4	45	0·707	0·000	10·10	7·141	0·000	7·42	5·246	0·000	6·03	4·263	0·000
5	60	0·500	−0·500	10·55	5·275	−5·275	8·00	4·000	−4·000	6·27	3·135	−3·135
6	75	0·258	−0·866	11·65	3·005	−10·089	9·60	2·477	−8·314	6·62	1·708	−5·733
7	90	0·000	−1·000	13·45	0·000	−13·450	11·95	0·000	−11·950	7·22	0·000	−7·220
8	105	−0·258	−0·866	15·45	−3·986	−13·379	14·18	−3·658	−12·280	8·23	−2·123	−7·127
9	120	−0·500	−0·500	17·32	−8·660	−8·660	15·87	−7·935	−7·935	9·40	−4·700	−4·700
10	135	−0·707	0·000	19·00	−13·433	0·000	17·10	−12·089	0·000	10·59	−7·487	0·000
11	150	−0·866	0·500	20·24	−17·528	10·120	18·00	−15·588	9·000	11·84	−10·153	5·920
12	165	−0·966	0·866	21·00	−20·286	18·186	18·55	−17·919	16·064	12·89	−12·452	11·163
13	180	−1·000	1·000	21·29	−21·290	21·290	18·86	−18·860	18·860	13·40	−13·400	13·400
14	195	−0·966	0·866	21·00	−20·286	18·186	18·55	−17·919	16·064	12·89	−12·452	11·163
15	210	−0·866	0·500	20·24	−17·528	10·120	18·00	−15·588	9·000	11·84	−10·153	5·920
16	225	−0·707	0·000	19·00	−13·433	0·000	17·10	−12·089	0·000	10·59	−7·487	0·000
17	240	−0·500	−0·500	17·32	−8·660	−8·660	15·87	−7·935	−7·935	9·40	−4·700	−4·700
18	255	−0·258	−0·866	15·45	−3·986	−13·379	14·18	−3·658	−12·280	8·23	−2·123	−7·127
19	270	0·000	−1·000	13·45	0·000	−13·450	11·95	0·000	−11·950	7·22	0·000	−7·220
20	285	0·258	−0·866	11·65	3·005	−10·089	9·60	2·477	−8·314	6·62	1·708	−5·733
21	300	0·500	−0·500	10·55	5·275	−5·275	8·00	4·000	−4·000	6·27	3·135	−3·135
22	315	0·707	0·000	10·10	7·141	0·000	7·42	5·246	0·000	6·03	4·263	0·000
23	330	0·866	0·500	10·07	8·721	5·035	7·25	6·378	3·625	5·92	5·127	2·960
24	345	0·966	0·866	10·05	9·708	8·703	7·20	6·955	6·335	5·85	5·651	5·066
			$A_0 + B_0$	+14·54			12·34			8·37		
			B_1		−5·95			−3·17			−3·47	
			B_2			+1·14			+0·58			+1·13

In each case A_1, A_2 etc., are zero, since the sine values cancel, the curves being symmetrical with regard to the centres of the bays. Thus $\tan\theta = \infty$ *i.e.* $\theta = \theta' = 90°$. The equations are therefore, for the three-armed wheel:

$$y = 14{\cdot}54 - 5{\cdot}95 \sin\left(x + \frac{\pi}{2}\right) + 1{\cdot}14 \sin\left(2x + \frac{\pi}{2}\right)$$

for the four-armed wheel:

$$y = 12{\cdot}34 - 3{\cdot}17 \sin\left(x + \frac{\pi}{2}\right) + 0{\cdot}58 \sin\left(2x + \frac{\pi}{2}\right)$$

for the six-armed wheel:

$$y = 8{\cdot}37 - 3{\cdot}47 \sin\left(x + \frac{\pi}{2}\right) + 1{\cdot}13 \sin\left(2x + \frac{\pi}{2}\right)$$

The above equations when plotted will give the shape of the rim very approximately at 14 revolutions per second, or in other words, will give the deflection of the rim past its zero position. Arrangements are at present being made to obtain the bursting speed of these flywheels, to compare with any theoretical bursting speeds which may be deduced from the above experimental results.

The author desires to express his thanks to Professor Warren, M. Inst. C.E., Wh.Sc., and to Mr. S. H. Barraclough, B.E., M.M.E., for their advice on many points during the course of these experiments, and to the former also for kindly allowing him the use of the workshop and appliances in the laboratory.

THE GEOLOGY OF MITTAGONG.

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[Communicated by Prof. T. W. Edgeworth David, B.A., F.G.S., F.R.S.]

[With Plates XXV., XXVI.]

[*Read before the Royal Society of N. S. Wales, October 7, 1903.*]

Mittagong on the main Southern Line is 77 miles from Sydney by rail, and about 30 miles from the coast. The town is over 2,000 feet above sea-level, and the railway rises gradually to Bowral, passing through the Gib tunnel at the foot of "The Gib." The following paper is the outcome of several visits to Mittagong during the past year, and represents field survey with subsequent laboratory work at the University. The area dealt with consists chiefly in that portion of the country lying between "The Gib" and Mount Jellore, and we have incorporated in our map a large amount of the field work done by J. B. Jaquet, during his survey of the iron ore deposits of the Mittagong district. The whole area, with Mittagong as a centre, comprises about 40 square miles. We propose to divide the paper into the following sections:—

I. Introduction.
II. Sedimentary Formations.
III. Eruptive Rocks.
IV. Petrological Descriptions.
V. Chemico-Mineralogical Classification.
VI. Age.
VII. Summary.

I. Introduction.

The huge eruptive mass of "The Gib"[1] has probably attracted attention from the time of the earliest settlers, and was termed trachyte by the earlier geologists.

Previous Observers:

Rev. W. B. Clarke in his "Sedimentary Formations," mentions occurrence of fossils in the shales.

C. S. Wilkinson, described the coal measures of Mittagong very fully in "Annual Reports Mines Dept. N.S.W., (1879, p. 215; 1882, pp. 141-2; 1890, pp. 206 – 11.)

J. B. Jaquet, Chapter IV., in his Memoirs on "Iron Ore Deposits of N.S.W.," treats of the Chalybeate Spring Deposits of Mittagong.

R. Etheridge, Junr., in "Invertebrate Fauna of the Trias," mentions Triassic fossils in the local railway cuttings.

E. F. Pittman, in "Mineral Resources of N.S.W.," mentions Iron ore deposits, p. 199 and p. 205; Diamonds p. 395; Mineral Water p. 448; Building stone pp. 444-5.

Mittagong is situated at the north-east extremity of a triangular valley whose apex divides the Mittagong Range at the angle nearest Bowral which is known as the Gap. This valley forms part of the watershed of the Nattai River, which runs northward through deep gorges in the Hawkesbury Sandstone. The Gib extends along the south-east boundary forming a large area of intermediate character. Standing on the Gib and looking north, we see first the Mittagong valley consisting of sandstones and shales which are altered and intruded by numerous dykes of trachytic character. Further northward, beyond a steep escarpment are the anthracite mines where the Newcastle measures outcrop, surrounding what is evidently the eroded boss of a syenite laccolite. Beyond are the steep gorges

[1] The name "Gib" is the popular abbreviated form of the name Gibraltar Rock" given to this mass on the Government maps.

of the Nattai and its tributaries which have cut down through the sandstone to the Permo-Carboniferous measures and exposed sills and laccolites of basalt and dolerite. Eight miles away the sharp cone of Mount Jellore stands out, a mass of trachyte with cones of basic rock near its southern slope. Ridges and cappings of basalt can be seen stretching from Mount Jellore west of the Gib to Berrima, but separated from the point of outlook by an extensive area of elevated sandstone hills. Towards the east another series of basalt flows is encountered, extending towards the Nepean. (See *Plate 25.)*

II. SEDIMENTARY FORMATIONS.

1. *Recent*—(*a*) Alluvial deposits.
   (*b*) Chalybeate deposits.
2. *Tertiary*-Ferruginous gravels and shales.
3. *Triassic*—(*a*) Wianamatta Shales.
   (*b*) Hawkesbury Sandstone.
4. *Permo-Carboniferous*—Shales sandstones, and coal measures.

1. *Recent Deposits.*

1. (*a*) The alluvial deposits formed of débris washed down from the hills, occupy swampy flats around "Woodlands," and necessarily

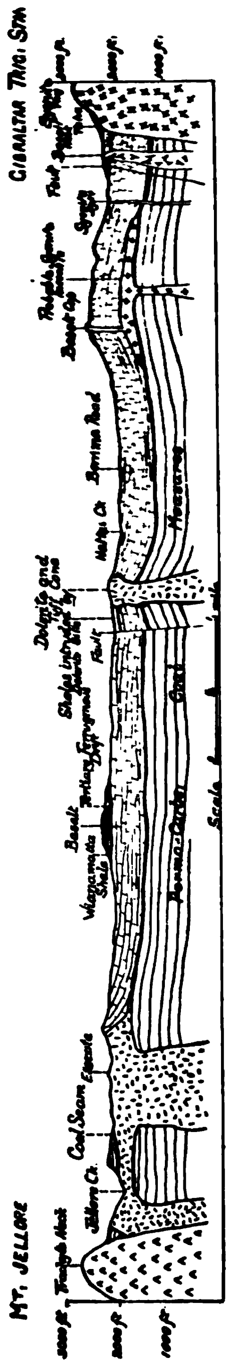

Fig. 1—Section A—G (see Plate 25) through the Mittagong district to "The Gib" to Mount Jellore. (For legend see Plate 25.)

obscure the true character of the country. (*b*) Very little has been said by previous observers as to the origin of the iron ore deposits of the district. They occur in two types. (1) Connected with basalt cappings situated on more or less elevated ground. (2) Deposits from ferruginous springs on low level ground.

We did not examine class (1) in detail as they are of no economic importance. Their mode of origin has already been referred to.

As regards the second class of deposits, they occur usually on the lowest ground in the vicinity; they are irregular shaped shallow masses of no very great magnitude (running up to 150,000 tons). In most cases the deposition can still be seen going on, in one or more small springs occupying crater-shaped depressions on the surface. The best known of these deposits occurs close to the Fitzroy Iron Works and has an area of 5½ acres. Three of these "craters" appear on the surface. From one of these there is a considerable flow of water, another gives a small trickle, the third none at all. The water is used medicinally by the residents and contains besides other mineral substances ·0712 parts per 1000 of bi-carbonate of iron. The deposition of the iron is brought about in the shallow crater-like depressions by exposure to the air, when carbonic acid is evolved and the iron is deposited as a hydrated peroxide. The composition of a sample of this ore analysed in the Department of Mines is as follows:—

Hygroscopic moisture (100° C.)	1·44
Combined water	10·97
Ferric oxide	70·58
Silica	12·42
Phosphorus	·03
Alumina	·76
Lime	·10

Magnesia	·55
Alkali oxides	·48
Sulphur	·039
Titanium	trace
Manganese oxide	2·44
Total... ...	99·80

Most of the above information has been drawn from Mr. J. B. Jaquet's book on the Iron Ore Deposits, which contains a very full description of this ore body, but one point which seems to have escaped previous observation is the presence of a large dyke intersecting the deposit close to the main spring. This dyke is best seen in a small road cutting close to the blast furnace about 200 yards away, where it appears as a white trap about 25 yards wide, and has a narrow parting of talcose rock. The position of the dyke is evidently a fault fissure as seen by a cross section of it (*vide* fig. 2). The dyke narrows down as it passes through the ore body and is lost some distance on the other side.

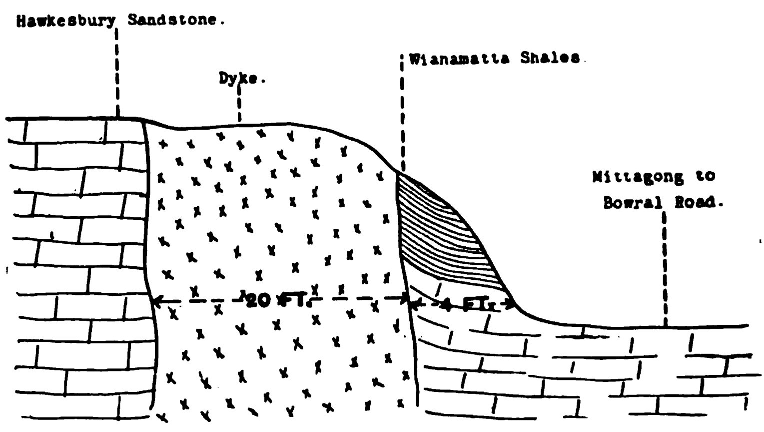

Fig. 2—Sketch of Section of dyke which intersects the iron ore deposit. (The section is taken through the dyke 200 yards to the north-east of the deposit.)

This type of deposit is common from near Picton as far south as Goulburn (*vide* J. B. Jaquet's report). One point to be noticed is that these deposits only occur in the vicinity of Post-Triassic volcanic action. The faulting and cracking of the sedimentary formations due to this action would allow the escape of the chalybeate waters to the surface, and consequent deposition of the ore. As to the source of the iron in the spring water, there are two possible hypotheses—that the iron was dissolved (*a*) out of the sedimentary rocks, (*b*) out of the eruptive rocks.

(*a*) Dealing first with the possibility of its being derived from the sedimentary formations, we should expect to find this type of deposit scattered over the Permo-carboniferous coal basin, and that instead of occurring more abundantly near the periphery, as is the case, such ore deposits would be more extensive towards Sydney the centre of the basin. The iron certainly could not be obtained from the Hawkesbury Sandstones, because of their small iron contents; so that if obtained from the sedimentary formations it would in all probability be derived from the coal measures. Objections to this would be that whilst the coal measures occur over so large an area in the east of New South Wales the iron ore deposits are limited; also that water taken out of the coal seams does not contain nearly so large a percentage of iron.

(*b*) The eruptive Intermediate rocks of the district contain slightly more than 8% of ferric oxide. Mr. Jaquet estimates the amount of iron ore as 150,000 tons containing 70·58% ferric oxide. The decomposed syenite appears as a white trap, and would only contain a trace of iron, so that we may say that 8% of the ferric oxide in the rock is leached out during decomposition. Then we find to produce the iron ore deposit 1,323,300 tons of syenite would be required. Taking the specific gravity as 2·6 this is equivalent to 18,185,230 cubic feet.

Now suppose that the iron ore was derived from the decomposition of the dyke which intersects it, suppose that the decomposition reached as far as the coal seam, and the dyke to have an average width of 10 feet, then the deposit would represent the decomposition of the dyke for a length of over 3,000 feet. Objections to this assumption—that the iron has been leached out of such a length of the dyke and deposited at the one spot are

1. The dyke is only seen to outcrop at the surface for a length of about 2,000 yards.
2. That part of its iron contents went to build up another ore body situated further along the dyke.
3. Iron derived from the decomposition of such a length would not under ordinary circumstances reach the surface at the same point.

Now the point where the iron ore deposit occurs is about the lowest part of the valley between the Gib and the dome shaped hill over the anthracite mines, this can be readily seen on examining the accompanying section.[1]

The sedimentary formation both next the Gib and in the anthracite valley is slightly tilted upwards by the syenite,

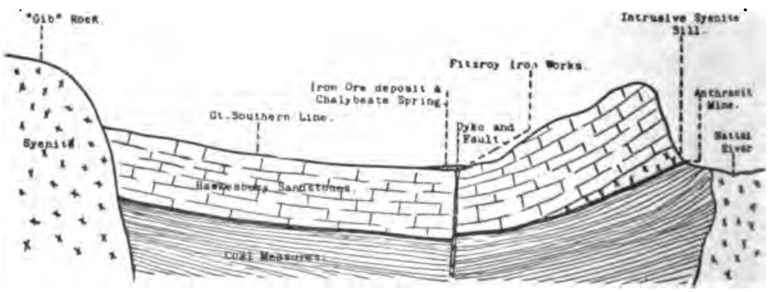

Fig. 3—Section across the Mittagong Valley, showing the probable origin of the chalybeate deposits.

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[1] This section is drawn approximately to scale, the data has been drawn largely from Mr. Jaquet's map.

and as the coal seams are porous it is evident that a fair amount of soakage must take place into the coal seams from either side of the valley, which would later on rise up to the surface through any available cracks such as dyke and fault fissures, etc. Moreover as the coal seam is intruded by the eruptive rock in the anthracite valley, and as at least 20 feet of it next the seam is decomposed into a white trap, it is only natural to suppose that all the iron from it has been dissolved out by the water circulating along the seam, this iron augmenting the supply if not furnishing almost the whole of that rising to the surface in the waters of chalybeate springs. Summary of arguments in favour of its origin from the eruptive rocks :—

1. In most of the decomposed dykes of the district a narrow parting of limonite occurs between the dyke rock and the sedimentary rock.
2. That these springs are always found in the vicinity of eruptive rock.
3. What has become of the iron leached out of the trap in the anthracite valley? It could not have run directly into the Nattai, as the dip of the strata is inwards.
4. The iron ore contains all and only the constituents of the eruptive rock, even to Titanium, which is usually uncommon in sedimentary formations.
5. It could not be derived from the sedimentary formations for reasons already given under that head.

2. *Tertiary Deposits.*

The drifts and gravels occur almost invariably wherever the basalt caps have protected them from denudation. They consist of rounded fragments of quartz and basalt cemented together by ferruginous material so as to form a conglomerate, which usually occurs as rounded blocks around the edges of the overlying basalt. The contained basalt

indicates that the drift was partially derived from lavas earlier than the basalt capping. The iron cement was either leached out from the later covering of basalt or, as at the time of deposition these gravels occupied the river beds, it may have been derived from contemporaneous chalybeate springs.

3. *Triassic Deposits.*

(*a*) The Wianamatta shales extend over a considerable area of the district, and largely occupy trough faults and areas of depression, as in the Mittagong valley. The thickest beds in our district occur at the north entrance of the Gib tunnel where they are 80 feet thick. Inspection showed they had been preserved by a capping of basalt, which has since been denuded away with the exception of loose boulders on Hynde's Farm.

(*b*) The Hawkesbury Sandstone occurs as beds 600 feet thick. Much has been turned into quartzite of varying degrees of hardness through alteration by "the Gib" and other centres of eruption. To this latter cause also must be ascribed the occurrence, in a glassy quartzite in a cutting on the Joadja tram line near Currockbilly, of bright glistening particles of graphite about 1 cubic millimetre in size.

4. *Permo-Carboniferous Deposits.*

These have already been described very fully by W. S. Wilkinson, as noted previously. Three well defined areas occur at Mittagong:

(*a*) Anthracite valley at head of the Nattai River.

(*b*) At the end of Mittagong Coal Co's tramway on Nattai River, four miles below (*a*).

(*c*) Extensive series of shales near Powell's Creek and Jellore Creek.

With respect to the first outcrop Mr. J. B. Jaquet says: "These beds are exposed to the north of Mittagong, where

the strata have been forced up by igneous intrusion and the Nattai has cut through the overlying Hawkesbury Sandstones."

The second area is reached by way of the old tramway which leaves the Berrima road on the right about four miles to the north-east, passing over high trestle bridges and through a tunnel excavated in the Hawkesbury series. In many of the cuttings towards the end fine specimens of decomposed dykes can be seen. From the end of the line a very steep inclined tramway brought the coal up several hundred feet from the adit just above the river. A very fine section of the Newcastle series and overlying triassic rocks can be seen in the cliff face above the adit.

The main point of interest in the third area is the occurrence of an impure graphite representing the coal seam highly altered by the intrusion of eruptive rocks.

III. Eruptive Rocks.

The district is very rich in eruptive rocks of the following types:—

1. Alkali-felspar, Intermediate series.
   - *a. Syenite*
   - *b. Trachyte.*
   - *c. Intermediate Tuffs and Breccias.*
   - *d. Trachytic dykes.*
2. Basic rocks including Picrites.
   - *a. Dolerites.*
   - *b. Essexites.*
   - *c. Basalt.*
   - *d. Basic Tuffs and Breccias.*
   - *e. Basic dykes.*
   - *f. Ultrabasic series of Jellore.*

1.—*a. Syenites.*—The most important area of this class is of course the huge dome of the Gib. Its summit stands

2,830 feet above sea level, rising about 1,000 feet above the surrounding country. It consists of a syenite allied to Bostonite (Harker, p. 117) consisting chiefly of orthoclase

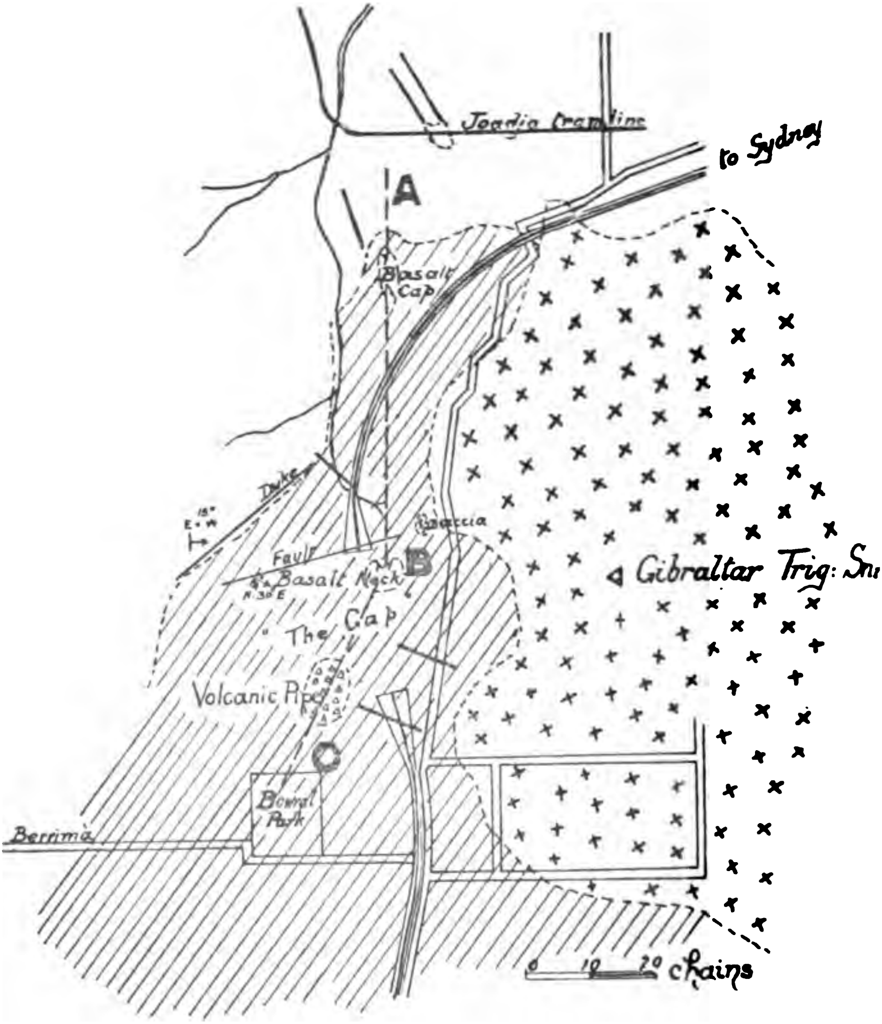

Fig. 4—Map of the district to the west of the Gib; showing volcanic necks and dykes. (For legend see Plate 25.)

felspar. It covers an area of 450 acres, and is surrounded by tilted sandstones on the northern side, while the east slope is overlaid by later basalts. The stone is largely used for building purposes and is obtained from seven quarries on the steep southern and western faces. Of these the most eastern (Loveridge's) is the largest. The rock is of very uniform character though the stone from Saunder's Quarry nearer Mittagong is of darker hue than that further east. Probably the lighter colour of the latter is part due to its proximity to the Hawkesbury Sandstone. It is remarkably free from fissures and cross cracks, and so it is possible to obtain huge blocks for architectural purposes. Narrow segregation veins of beautiful sanidine (glassy orthoclase), mingled with large hornblendes and ægerine crystals, traverse the syenite. Small irregular grains of fluorspar are fairly common in Loveridge's quarry, while sparkling little quartz geodes can be found in western quarries. Small black fragments and stains of carbonaceous material are present. These are supposed to be due to the condensation of bituminous matter carried up by volcanic rock, in a gaseous state, from the underlying coal measures.

The Gib represents the denuded plug of an old volcano. It is improbable that it represents a denuded laccolite, since only a very few hundred feet of shales, judging from surrounding strata, could have remained undisturbed to check the immense volcanic energy of so large a mass of molten magma.—(See Section IV. No. 1.) Again although any ejectamenta which may be present on the eastern slope have been covered by basalt, and much have undoubtedly been removed by denudation, yet what appears to be an ejected breccia occurs at the foot of the western slope. There is also a true trachytic lava which probably welled up from a parasitic cone, but this is described more fully later on. (See 1. c. *infra*).

Another large area of syenite occurs in the Nattai Valley near the anthracite mines, concerning which Jaquet writes: "This great mass has forced the strata upward and formed a dome, while at the same time sheets have run along the bedding planes of the coal measures. One of these sills, which has a thickness of over 100 feet has followed the roof of the coal seam upon the south side of the valley, and is in actual contact with the coal. The coal is, however, comparatively unaltered." The syenite sill has decomposed into a trap closely approaching kaolin and has been mined by local residents.

1.—*b. Trachytes.*—A small quarry for local purposes, chiefly roadmending, has been opened in a hill about one and three-quarter miles from Mittagong, along the Berrima road. The rock is a trachyte, and some fine examples of columnar structure were to be seen, but have probably since been broken up. The columns are composed of bluish rock with a somewhat spotty appearance, and readily crack off in large flakes.

Mount Jellore.—This striking cone rises abruptly out of the Triassic sandstones. The south face has slopes of 60° and rises sharply up from Jellore Creek. A steep ridge runs towards the west composed of quartzites, etc., which are intruded by trachyte dykes, especially near the Peak. From the Trignometrical Station (height 2,734 feet above sea level) a magnificent view northward over the Wollondilly River can be obtained. The top consists of a fine grained greenish rock which is jointed so that the slabs dip away from the centre. The lava composing the cone appears to have differentiated largely during the process of solidification. The summit is composed of a trachyte consisting of felspars more or less kaolinised, and irregular bunches of blue hornblende, giving a mottled appearance to the hand specimen. About 200 feet from the summit

the track crosses a large outcrop of rock, which is gray on the weathered surface, but when broken into discloses a dark blue colour like that of the basalts. This rock breaks readily into flakes with a conchoidal fracture, the non-basic character of the rock is shown by the fact that the flakes are translucent on thin edges. This outcrop was of large extent, but the boundaries were either hidden by talus slopes, or formed cliffs which rendered mapping almost impossible. This dark trachyte contains a large proportion of ægerine (soda augite) in its composition.

A similar association of trachytes of like composition occurs in the Glass House Mountains, Queensland. Indeed several sections made by Mr. H. I. Jensen from rocks brought by him from that locality show minute microscopical resemblance. The blue hornblende mentioned above also occurs in the trachytes of the Warrumbungle Mountains near Mudgee. This similarity in structure in the trachytes extending along the western slope of the present Dividing Range is of much interest and will doubtless repay investigation. (See Section IV. Nos. 2 and 3).

1.—*c. Intermediate Tuffs and Breccias.*—The tuffs are in all cases much decomposed and in many instances merge into breccias.

(1) Tuff cone, half mile west of the Gib.
(2) Tuff bed, one and a half miles on Berrima road.
(3) Tuff, west slope of Jellore.
(4) Tuff, three miles east-north-east of the Gib.

(1) This volcanic cone rises sharply from lower levels round Bowral, just to the west of the southern end of the tunnel. The top is fairly flat and oval in shape, being approximately 100 yards long by 30 yards wide. The cone is composite in character, the eastern slope consisting of decomposed syenitic breccia and vesicular lavas in which the steam holes have been filled with calcite. Towards

the south the rock becomes darker and harder and has been mistaken for a basic breccia. In sections, however, it is seen to be composed largely of fragments of trachyte. The south-west end has been quarried for light colored rock of a tuffaceous character. On the north-west slope more vesicular lava (much decomposed) occurs. (See Section IV. No. 4.)

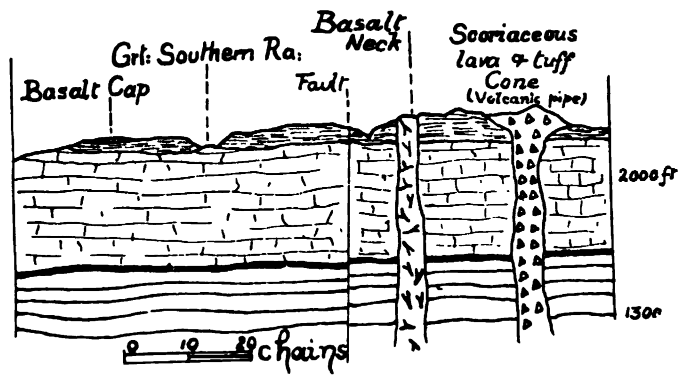

Fig. 5.—Section A B C (see fig. 4) showing small volcanic necks to the west of the Gib.

This cone probably does not represent the remains of the crater of the Gib, but is the result of material which has welled up from a laccolite some hundreds of feet below. The large area of sandstone to the north of this cone has been upheaved to a considerable extent as shown by the dip of the strata. It is worthy of note that the fragments included in the tuff resemble (when sectioned) the rock quarried from a small hill about one and half miles away on the northern slope of this same elevated sandstone area. This would tend to show the existence of a mass of eruptive material below the sandstone, in form of a laccolite, extending from the quarry on the north to the tuff cone on the south.

(2) Berrima Road.—This is a fairly extensive bed extending about 100 yards along the road and 50 yards back on the northern side. It is not so decomposed as many of the tuffs. Fragments of shale and sandstone are enclosed. This bed was probably formed at the time of eruption of the neighbouring mass of trachyte mentioned previously.

(3), (4) These tuffs are very much decomposed and are of little use for stratigraphical purposes.

1.—*d. Trachyte dykes.*—The whole district round the Gib, but especially for a few miles to the north, is permeated with dykes. Over fifty have been mapped by us. As before mentioned, these dykes have to a great extent determined the contour of the country. Although the dyke itself is almost invariably decomposed to a soft trap of light colour, yet the intruded rocks have been very much hardened, the sandstone into quartzites and shales into chert. Hence the hard quartzites resisting erosion have in many cases formed the crests of ridges. We found it to be the rule that almost every small hill owes its existence to the presence of dykes or other volcanic action.

The areas of subsidence are in many cases bounded by long dykes which have evidently intruded the planes of weakness. One example of this class occurs running north and south along the slope of the sandstone hill to the west of the Gib. Here the junction between the later Wianamatta Shales and much more elevated Hawkesbury Sandstone is marked by a decomposed dyke. The dykes are usually three or four feet wide and can sometimes be traced for half a mile.

2.—*a. Dolerites.*—One of the finest specimens of dolerite in the State occurs on part of a small hill now occupied by a private garden, about three-quarters of a mile east-north-east of Mittagong Station. It is found in form of large subangular boulders which are extremely hard. The

surface is slightly weathered but inside the rock is quite undecomposed. It breaks with a ring like phonolite, and pieces fly away to great distances. The dolerite appears to have intruded an isolated patch of syenite (much decomposed). The actual line of junction is completely hidden by the clays etc., resulting from the latter. The rock makes a beautiful micro slide, a description of which will be found in the petrological section (No. 5).

In the Nattai River at the foot of the incline leading to the Mittagong Coal Co's. adit, is a large mass of dolerite which probably represents a laccolite. Numerous sills have spread out horizontally between the Permo-Carboniferous Shales. The latter are converted into a black chert somewhat resembling rhyolite macroscopically. The bed of the river from the adit downwards appears to be cut out of this dolerite. The latter varies in texture and passes into a basalt zone about 20 feet thick at its junction with the coal measures, due to its rapid cooling. Several bluffs, some 40 feet high, some with prismatic structure, are cut through by the river a little lower down. On the east bank, 200 yards down from the adit, there are some broad dykes of lighter colour, consisting mainly of felspar and magnetite.

"Currockbilly," three miles along Joadja Tram Line.—This prominent hill consists of intermediate rock on the east, which is much decomposed, but the lower western portion is formed of dolerite and decomposed tuffs. A large broad dyke appearing as red soil runs about one mile east from this centre and a good section (already described) is shown in cutting on Mittagong Coal Co's line. Sills of dolerite, two feet thick, in the shaley bed (Wianamatta) of Kells Creek, south of Currockbilly, probably originated in the above boss. Much of the low lying country in this

locality is covered with dolerite which may represent a sill exposed by denudation.

2.—*b. Essexites.*—This rock is a variety of dolerite containing some orthoclase, a varying amount of biotite, with ilmenite and analcime, as well as the ordinary constituents of dolerite, *i.e.* plagioclase and augite. The majority of the basic rocks of Jellore have somewhat similar composition, though biotite is rare. It will be seen that the chemical composition agrees fairly closely with Brogger's essexite from Gran. Chant's farm, Jellore, is situated between two hills of essexite, though here the rock is mostly decomposed into a brownish soil. It is surrounded on the north and west by tilted quartzites which have a crater-like appearance, as they stand a little above the level of the soft essexite. This oval neck of essexite is probably the parent of the sills of similar rock which appear quite uniformly underneath the Permo-Carboniferous shales in the neighbourhood. The rock occurs almost undecomposed in Jellore Creek just above Chant's smaller selection at the foot of Mount Jellore. (See Section IV., No. 6.)

2.—*c. Basalts.*—Basalt occurs as dykes, necks and cappings. The two former have already been described. The basalt cappings form a very noticeable feature round Mittagong. They are usually easily identified from the fact that they have almost all been cleared by the settlers. They weather into a rich red soil very suitable for agriculture, and hence all such areas have been occupied for many years. The basalt usually occurs as angular boulders about the size of a football. These have a brownish weathered surface, often pitted with small holes, but are very hard within. This structure is due to jointing which lends itself to disintegration and is probably present many feet below the surface. Another example of this jointing occurs in the deep quarry at Dundas. The long ridges of basalt are

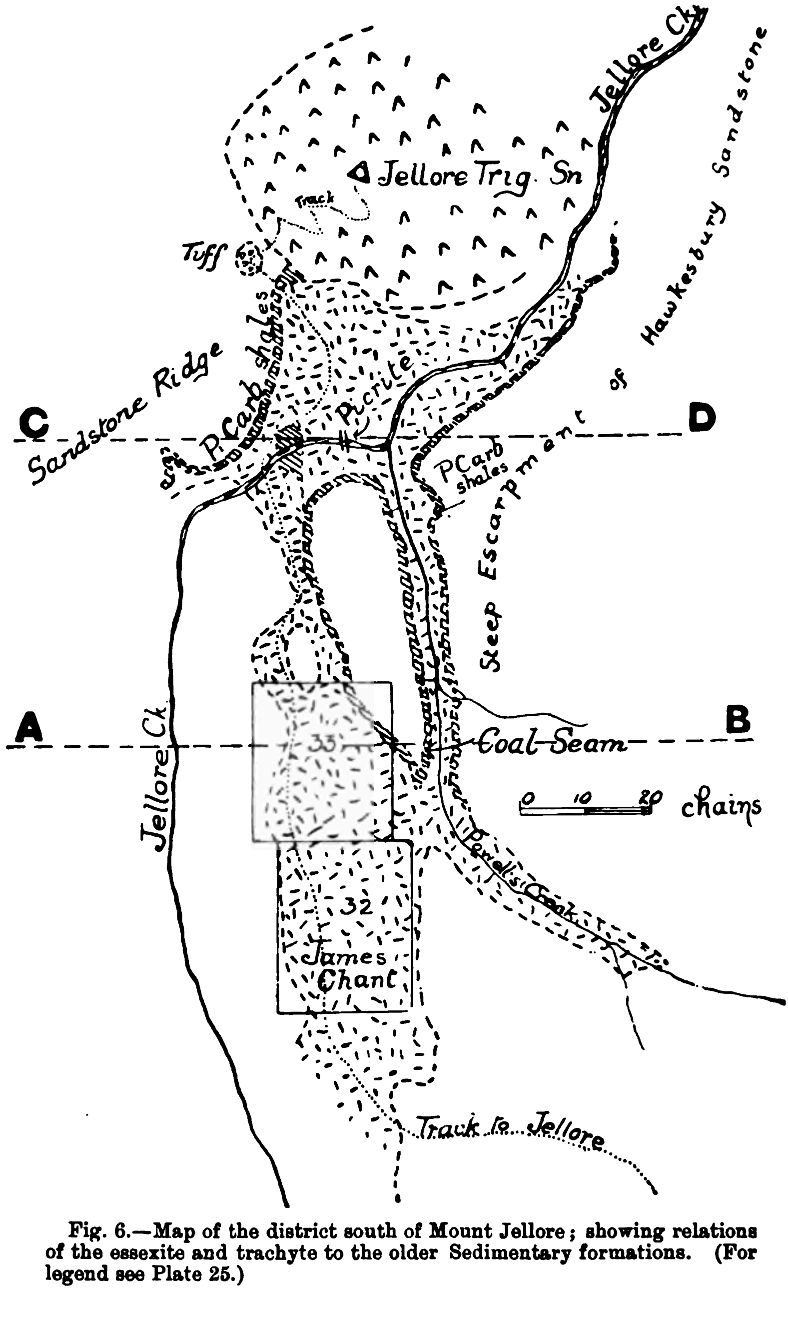

Fig. 6.—Map of the district south of Mount Jellore; showing relations of the essexite and trachyte to the older Sedimentary formations. (For legend see Plate 25.)

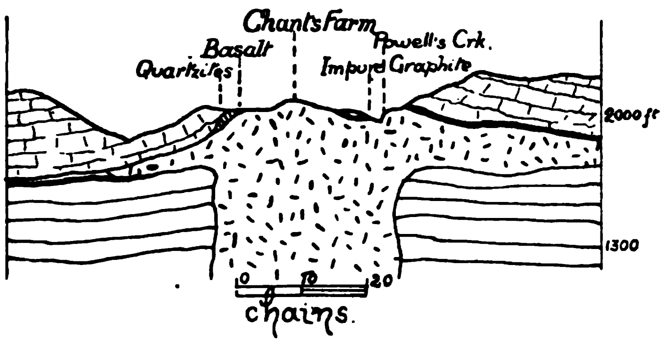

Fig. 7.—Section A B (see fig. 6).

due in many cases to their filling old river valleys. Ensuing denudation has caused these ancient depressions to stand up as ridges. The very varied texture of the basalts obtained from localities near Mittagong is well shown by the sections. (See Section IV., Nos. 8 and 9.)

2.—*d. Basic Tuffs and Breccias.*—

1. Shaft over Gib Tunnel, (north end).
2. Tuff on Currockbilly.
3. Tuff near Frasers Hill.

1. This example of basic breccia occurs in the spoil heap excavated from the shaft used in building the Gib Tunnel. A large quantity of Wianamatta shale has also been tipped here. The breccia is composed of fragments of shale, micaceous sandstone and older basalt enclosed in a dark matrix of basalt. It also contains large lumps of what appear to be orthoclase. These fragments have evidently been torn from the sides of the fissure through which the basalt welled. Close alongside and a little nearer the road is a basalt knob, which probably marks the centre of the boss. The former is a fine specimen of basic breccia not being at all decomposed. We were informed that this basic neck gave much trouble in excavating the tunnel.

2 and 3. These tuffs were much decomposed and of no special interest.

2.—*e. Basic Dykes.*—Two large basic dykes occur in cuttings on the Mittagong Coal Co's line near Kell's Creek. They are highly decomposed, but are undoubtedly formed of dolerite in the centre, with a zone along the sides of a fine grained rock. The latter presents the same characteristics as that constituting the more common dykes of the district termed by J. B. Jaquet, syenite. That the more acid rock should separate out first in a rock magma is quite contrary to the commonly accepted law. Hence it seems possible that many of the decomposed dykes of the district are basic and not intermediate. This view is also strengthened by the fact that in other parts of the district where sections of the dolerite can be obtained (as at Mittagong Coal Co's adit) the dolerite is always fringed by a narrow belt of basalt. The above dykes are similar in structure and of sufficient interest to warrant a description of one of them. The second one occurs in a cutting about one-third of a mile past Kell's Creek. The sides are bounded by quartzites exhibiting slickensides and interpenetrated by smaller dykes. Bands of limonite and chalcedony occur near the edges. Its direction is 10° East of North, and width about two chains. It is undefined to the south but extends some distance to the north. The dolerite has weathered into spheres with concentric crusts.

2.—*f. Picrites.*—In the channel of Jellore Creek, about half a mile above its junction with Powell's Creek occurs the following series of dolerites and picrites. About one-third of a mile below the clearing (on the path from Chant's Farm to Mount Jellore) the creek cuts through a dyke of coarse-grained dolerite weathering spheroidally but containing undecomposed pieces in the interior. This is 30 yards wide and carries a little pyrites. Then come 15 yards

of greenish quartzites. Next 5 yards of a fine grained rock, followed by 70 yards of shaley sandstone showing well marked prismatic structure. A clear junction with the next rock a coarse dolerite, can be seen, trending 60° east of north. The dolerite contains small zeolites, probably natrolite. Lower down the rock contains square pieces of shale. Twenty yards further a decomposed cliff of very basic black rock occurs. This has altered on the surface to a greenish-grey powder and weathers into spheroidal boulders. A section of rock obtained from centre of a boulder shows it to be a picrite containing much magnetite and pyrites. On the southern bank is a high bluff (75 feet) of rock with granitic texture but which turns out to be a kaolinised dolerite. (See Section IV., No. 9.)

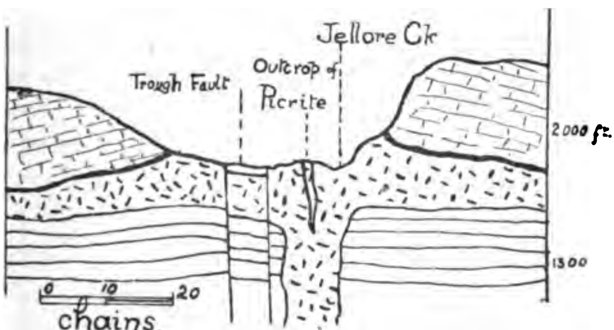

Fig. 8.—Section C D (see fig. 6).

IV. Petrological Descriptions.[1]

This section is accompanied by microphotographs of four of the most interesting rocks of the district, see *Plate 26.* The chief type of each group of rocks will be described petrographically in some detail first, and any points of interest in other similar rocks then noted. The percentages of constituent minerals given are, in the case of the finer

[1] A list of the Rock Sections described herewith will be found at the end of this Section IV.

grained rocks, only approximate. Under the head "Order of Consolidation," small tables are given showing approximately the relative age and duration of the mineral consolidation. Ordinates may be taken to represent starting points, while abscissæ indicate periods during which crystallisation went on.

No. 1. *Locality* Loveridge's Quarry, Bowral.
(See *Plate 26*, fig. 1.)

Texture—Hypidiomorphic granular.

Fabric—No base is present. The rock is composed almost wholly of a mass of orthoclase with some grains of ilmenite and a fair amount of indefinite dark coloured decomposition products.

Minerals present (in order of decreasing abundance)—

Orthoclase	...	85%
Decomposed ferromagnesian minerals	...	10%
Magnetite and ilmenite, Apatite, Fluorspar — accessory	...	5%
Calcite and chalcedony—secondary.		

Orthoclase occurs as sub-angular crystals, some of square or rectangular shape. Although some few of the felspars are clear and transparent, yet the majority are kaolinised. Some are converted wholly into a grey powdery mass, while others show included parallel rows of brownish coloured matter. The latter arrangement is due to the fact that cleavage planes offer the easiest point of decomposition. Many of the prisms show clear borders while the remainder of the crystal is more or less kaolinised. Twinning is fairly common, after the Carlsbad law.

In some sections irregular patches of secondary *iron oxide* occur. They have a somewhat fibrous structure and are perhaps due to decomposition of hornblende or other ferromagnesian mineral.

Magnetite is present in small black opaque grains, sometimes it is aggregated into a long narrow row of grains. It is also included in both clear and kaolinised felspars and is often surrounded by a border of brownish matter, due to the colouring of the kaolin by iron. The magnetite is best examined by reflected light which also shows up the kaolin well.

Grains of *ilmenite* are common, and are invariably partly altered into leucoxene. Small grains of the latter are scattered through the section, and in reflected light, stand out a purer white than the kaolin.

Among accessory minerals *apatite* is very abundant as small needle-shaped prisms and hexagonal basal sections. These prisms occur in small bunches in the felspars. Central enclosures of higher refractive index occur in the needles.

Fluorspar as irregular blue isotropic patches is present.

Calcite and granules of chalcedony line irregular spaces in some slides. These however are obviously secondary.

Order of Consolidation.

Apatite

Magnetite Ilmenite

Hornblende ?

Orthoclase

Fluorspar
Calcite
Chalcedony

Name.—The rock is a SYENITE allied to bostonite. The latter (*vide* Harker, p. 117) is a rock consisting essentially of felspar, the ferromagnesian silicates being typically absent. According to the new classification based on chemical analysis the rock is named *boxolanose.*

No. 2. *Locality* Mount Jellore, 200 yards from top on west side.

Texture—Pilotaxitic.

Fabric—Hypautomorphic-granular. Rock consists of a groundmass of small felspars and small fibrous aggregates of green soda-augite (aegirine). Larger felspars of lath shaped habit are scattered irregularly through the mass, together with aegirines which are as a rule somewhat smaller than the former.

Minerals present (approximate area)—

Felspar (orthoclase and sanidine)	... ...	90%
Aegirine ...	... ...	10%
Magnetite, Arfvedsonite	(accessory).	

Felspar—The larger crystals are usually broken and angular. Many are singly twinned and comparatively long and narrow. These are of variety sanidine. The small felspars of the groundmass are of granular habit with ill-defined edges.

Aegirine—In long ragged laths of green-brown colour.

Arfvedsonite—A slate-brown mineral visible with high power in the groundmass in some quantity, is referable to this variety of hornblende.

Magnetite in small grains is present.

Order of Consolidation.

Aegirine	
Felspar	magnetite
	aegirine and arfvedsonite
	felspar

Name.—The rock is evidently a trachyte. From comparative abundance of aegirine it may be termed AEGIRINE TRACHYTE. It may be mentioned that this rock was stained, after acting on section by hydrochloric acid, in order to

test for nepheline. No definite result was obtained, the small amount of mineral which absorbed the stain being very probably a decomposition product.

No. 3. *Locality* Top of Mount Jellore.
(See *Plate 26*, fig. 2.)

Texture—Hypautomorphic granular. No base is present, but rock consists of a mixture of somewhat rounded grains of orthoclase mingled with larger but less abundant quartz. In some parts of the slide the interstices are filled with a strongly pleochroic hornblende.

Minerals present (approximate area)—

Felspar (few small phenocrysts)	85%
Quartz	10%
Hornblende	5%

Felspar is all somewhat kaolinised. The majority have the form of short laths and a few are singly twinned. No plagioclase is distinguishable.

Quartz is subordinate in shape, of clear undecomposed grains.

Hornblende has the form of irregular masses with a somewhat poikilitic structure. It occurs in bunches surrounding felspars throughout the section. The colour in ordinary light is bluish-green. It shows intense pleochroism changing from olive-green to myrtle green, and seems to be most closely akin to arfvedsonite. (See *Plate 26*, fig. 2 and Analysis I.)

Order of Consolidation.

Felspar

Quartz

Arfvedsonite

Name.—This rock is on the borderline between trachytes and syenites, and contains too much quartz to be a typical trachyte. It seems to be similar to the quartz-syenite of

Bear Paw Mountain (Montana) described by W. Weed and L. Pirsson, (Am. Jour. Sc., May 1896) but is of finer texture. Perhaps ARFVEDSONITE QUARTZ TRACHYTE is a suitable name.

Other trachytes of the district.—A hard bluish trachyte can be obtained from a quarry on the east side of the Berrima road, about one and a half miles from Mittagong. The felspars are decomposed somewhat and of two generations. Large corroded augites are sparsely scattered through the mass.

No. 4. *Locality* Southern End of Cone near Gib. Tunnel.

Light brown glassy matrix containing subangular grains of quartz, and fragments of trachyte. The latter consists of small felspar laths showing flow structure. Magnetite is present chiefly in the trachyte fragments but also in the matrix. Patches of secondary calcite are fairly abundant. None of the rocks of the neighbourhood resemble the included trachyte very closely, except the trachyte exposed in the quarry on the Berrima Road, about two miles from Mittagong, which also contains grains of magnetite.

Name.—The rock is evidently a tuff, composed largely of fragments of trachyte, and may therefore be termed a TRACHYTE TUFF.

No. 5. *Locality* $\frac{3}{4}$ miles E.N.E. of Mittagong Station, in private ground.

Texture—Pilotaxitic. Large plagioclase phenocrysts.

Fabric—Hypidiomorphic groundmass of felspar, augite and magnetite, which are confusedly mixed together. The felspar appears to be last formed, since in several instances it has developed round the other two minerals.

Minerals present (approximate areas)—

Felspar	80%
Augite	12%

Magnetite 7%
Apatite
Analcime

Felspars are of two orders. The large phenocrysts are of square or oblong section all showing polysynthetic twinning, some after albite and pericline laws, others albite and carlsbad type. Many crystals contain small patches of kaolin and other indefinite decomposition products. The felspars of the groundmass occur in laths, and are most usually multiple twin forms. By Becke's method their R.I. is higher than Canada balsam, and hence they are basic plagioclase.

Augite is mainly in form of large rounded grains, some however showing a well defined octagonal crystal form. Colour is a sage-brown with very feeble pleochroism. The crystals are undecomposed but show characteristic cracks; inclusions of magnetite are not uncommon.

Magnetite as small black crystals of square or triangular shape. It is also disseminated through portions of the slide in form of dust-like particles and clustered into small aggregates.

Apatite is very abundant in form of colourless prisms and hexagonal cross sections. The crystals are rather larger than usual in dolerites.

Irregular patches of clear colourless isotropic material of fairly large size with low R. index are probably *analcime.*

Order of Consolidation.

Felspar (Phenocrysts) |
| magnetite, apatite
| augite
| felspar

Name.—The rock is a DOLERITE very much like that figured in Harker's Petrology (fig. 42).

Other dolerites of the district.—Fine specimens for rock section purposes can be obtained from the Nattai River cliffs, just north of the incline terminating the Mittagong Coal Co's. tramline. Microscopically the sections are seen to contain plagioclase, augite and magnetite, with accessory calcite and apatite. The various rocks are characterised by special texture or constituents. Thus in B. 23, under high power, beautiful little hexagons of a brown mineral can be seen. These are most probably micaceous hematite. Many of the dolerite masses have what appear to be less basic dykes (aplitic veins ?) running through them, B. 22 is of this type, consisting mainly of plagioclase. The dolerites from Jellore Creek approach picrite in composition. Augite and magnetite get more plentiful, while much serpentine is present. Pyrites often occurs as grains and prisms (E. 45). Chlorite showing pitted structure is common in some slides from this locality.

No. 6. *Locality* Jellore Creek at foot of Mount Jellore.
(*Plate 26*, fig. 3.)

Texture—Hypidiomorphic granular.

Fabric—No base is present. The rock consists of an intimate mass of augite, felspar and ilmenite.

Minerals present (% by weight. Rosiwal's method)—

Augite	30
Felspar	44·5
Ilmenite...	20

Apatite—accessory

Serpentine }
Calcite } secondary
Analcime }

The chief characteristic is the prevalence of *ilmenite* in long narrow ragged crystals representing sections of the usual tabular habit. The long axes are very approximately parallel, indicating perhaps some flow while the magma

was consolidating. The mineral is opaque with metallic lustre—by incident light of an iron-black tint. Almost all sections show partial decomposition into white opaque granular leucoxene. The latter occurs along cleavage cracks and is very well shown in one or two basal sections. Many ilmenite crystals contain parallel-sided apertures.

Augite occurs in irregular masses, which have filled in the spaces left by the felspar and ilmenite—though a few augites have a fairly regular hexagonal shape. It is sensibly ophitic, in many cases extinguishing simultaneously over comparatively large areas. The colour by transmitted light is pinkish-brown. None of the crystals are twinned. The augites are traversed by cracks along which incipient decomposition is taking place. Inclusions of *apatite* ilmenite and felspar are to be seen, due as stated above, to the later solidification of the augite.

The *felspars* occur in prisms, usually short and wide. Very few are polysynthetically twinned, the crystals being mainly untwinned or singly twinned. This fact and also the low refractive index (lower than Canada balsam in many crystals) points to a preponderance of monoclinic felspar. The felspars are decomposed into kaolin and replaced by brown chloritic material especially round the edges of the prisms. Many crystals include an isotropic glassy material of refractive index less than that of the felspars. This mineral is probably *analcime* which not infrequently occurs in such a manner.

The serpentine, together with the calcite and chalcedony present in the rock, may represent decomposed augite. The beautiful radiating tufts of *serpentine* show black crosses of aggregate polarisation.

The *calcite* can be distinguished by its pale neutral tints under crossed nicolls, and by the rhombohedral cleavage.

Order of Consolidation.

Apatite
Ilmenite
Felspar
Augite | Calcite, serpentine, kaolin, chlorite, leucoxene–(secondary)

Name.—The rock is allied to essexite. The latter is a variety of dolerite originally found near New York, which according to Rosenbusch is composed as follows :—

Labradorite or andesite. Orthoclase. Brown augite, with some biotite and hornblende. Olivine or its decomposition products. Apatite. Titaniferous iron. Analcime (in interstices of felspar).

Hence we see the resemblance is very strong. It may be called an ILMENITE ESSEXITE.

Essexites resembling the above may be found between Chant's Farm and Mount Jellore. The small cone just to the north of Chant's Farm affords a fine micro-section of decomposed essexite. The felspars are mainly replaced by chloritic material, but large apatites and beautiful leucoxenes, the latter after titaniferous magnetite, make the slide well worthy of manufacture.

No. 7. *Locality* 1 mile south of Mittagong Station.

Texture—Porphyritic, with large olivine phenocrysts.

Fabric—Hypautomorphic prismatic. Base consists of small laths of plagioclase mingled with grains of augite and magnetite, the whole enclosed in a dark brown glass.

Mineral present (approximate area)—

Glass	40%
Olivine	30%
Felspar	15%
Augite ... } Magnetite }	15%

Olivine occurs in comparatively large masses, usually of irregularly circular shape, but prisms and hexagonal cross sections are fairly numerous. The olivine has not undergone serpentinisation, and is therefore clear and colourless with well defined edges. The remaining minerals are much smaller and of the ordinary types occurring in basalts.

Order of Consolidation.

Olivine
felspar
magnetite
augite
glass

Name.—From the abundance and size of the olivine crystals the rock may be termed an OLIVINE BASALT.

No. 8. *Locality* McGuire's Creek, 7 miles east of Mittagong.

Texture—Hypocrystalline with large phenocrysts.

Fabric—Dense dark base consisting apparently of small grains of magnetite in a glassy paste. Small ragged laths of plagioclase and irregular masses of magnetite together with some olivine are scattered through the base. Large phenocrysts of felspar and olivine are noteworthy. The flow of the small felspars round these large crystals is well shown.

Minerals present (in order of decreasing abundance)—

Magnetite	80%
Felspar (of two orders)	10%
Olivine (of two orders)	3%

Plagioclase.—The small felspars are of usual lath shape and show twinning carlsbad and albite law, probably of variety labradorite. The phenocrysts are in some cases idiomorphic, while in others the edges are rounded and corroded. They are as a rule broader in proportion than the small felspars. The albite law of twinning is followed.

Olivine.—One large crystal is of a curious annular shape, evidently due to corrosion, showing a portion of the dark ground mass included within the crystal.

Order of Consolidation.

Olivine
Felspar
magnetite
olivine
felspar

Name.—Rock belongs to basalt family. The abundance of magnetite both in the base and in layer masses would seem to justify the name MAGNETITE BASALT.[1]

Basalts occur in great variety around Mittagong. In addition to those described above, mention may be made of the following:—

A basalt from the top of the sandstone hill one and a half miles north west of the Gib. A shaft has been sunk through this basalt, presumably to prospect for ironstone. In thin sections the basalt is characterised by large clear augites and felspars, olivine is abundant. The augites have a peculiar smoky colour.

A basalt from a small knob close to the Vice Regal residence at Sutton Forest, some miles south of Mittagong may be mentioned here. The small granular augites in thin sections are seen to be enclosed in a large mass of felspar showing poikilitic structure. This is rather rare in felspars.

Basalts presenting ordinary features can be obtained from Jellore Creek, Nattai River near the coal adits, Woodlands Estate, and the knob over the north end of the Gib Railway Tunnel.

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[1] N.B.—The above somewhat remarkable basalt lies outside the area of our map and was found during a walk to the abandoned diamond fields on the Nepean River.

No. 9. *Locality*, Jellore Creek, at foot of Mount Jellore, near Mittagong.

Texture—Hypautomorphic granular.

Fabric—No base is present. The rock is composed of comparatively large crystals of augite, together with masses of magnetite, serpentine and smaller crystals of plagioclase.

Minerals present (% by weight, by Rosiwal's method)—

Serpentine	38·0
Augite	24·5
Magnetite	13·0
Plagioclase	24·5
Pyrites, Biotite } accessory	

Serpentine has usual fibrous appearance due to decomposition of olivine. It is present both of rich green colour and as colourless fibrous tufts.

Augite.—Large idiomorphic crystals showing strong cleavage.

Magnetite is very massive in this slide and appears to have formed round the serpentine and felspars. Several of the latter are enclosed bodily.

Pyrites of yellow metallic colour by reflected light accompanies the magnetite.

Biotite occurs sparsely as small fibrous squares with strong pleochroism.

Order of Consolidation.

Serpentine (Olivine)

Augite

Plagioclase

magnetite

pyrites

Name.—Rock evidently belongs to ultrabasic group. Since some felspar is present it belongs to the picrites. From the size and abundance of the augite crystals it may be termed AUGITE PICRITE.

A brief description of the four microphotographs (*Plate 26*) is appended :—

Figure 1—Syenite from "the Gib." (The darker variety from Saunder's Quarry). This photograph shows the wavy appearance of the felspars due to kaolinisation. The opaque masses are chiefly ilmenite and magnetite, while the dark powdery material results from decomposition of the original ferro-magnesian mineral (probably hornblende).

Figure 2—Quartz trachyte forming summit of Mount Jellore. The dark material is the hornblende allied to arfvedsonite. The transparent masses are quartz. The remainder is chiefly felspar.

Figure 3—Essexite from Jellore Creek, showing long opaque ragged ilmenites, broad felspar laths and irregular darker masses of augite.

Figure 4—Augite picrite from Jellore Creek. Augite is characterised by the strong cleavage. The serpentine shows as dark cloudy masses. Felspar constitutes the colourless material. An exceptionally large mass of magnetite occupies one side of the photograph.

Reference list of rock sections described :—1. Syenite, Bowral; 2. Aegirine trachyte, Mount Jellore; 3. Arfvedsonite quartz trachyte, Mount Jellore; 4. Trachyte tuff, near the west slope of the Gib; 5. Dolerite, Mittagong; 6. Ilmenite essexite, Jellore Creek; 7. Olivine basalt, Mittagong; 8. Magnetite basalt, McGuire's Creek; 9. Augite picrite, Jellore.

A stereogram of the Mittagong District will be found at the end of this paper.

V. Chemico-Mineralogical Classification.

As the authors place great value on a new system of rock classification recently propounded by U.S.A. petrographers,[1] it is proposed to adopt their methods in classify-

TABLE OF ANALYSES.

	I.	II.	III.	IV.	V.	VI.
S_1O_2	66·68	55·86	55·16	46·22	43·31	39·91
Al_2O_3	14·63	15·25	16·67	9·38	16·68	13·67
Fe_2O_3	2·18	4·92	2·36	5·85	2·81	6·55
FeO	2·31	6·07	7·31	7·39	9·00	8·98
MgO	·30	·20	·56	3·08	10·56	11·96
CaO	1·88	2·13	2·30	10·80	7·95	6·18
Na_2O	6·12	2·34	5·65	3·21	2·94	1·28
K_2O	4·02	9·28	6·97	1·80	·97	·66
H_2O (100° C.)	·38	·70	·85	·94	·88	3·66
H_2O (+100° C.)	·83	·50	·88	2·30	1·72	3·74
CO_2	·05	1·80	1·50	4·46	·03	·40
TiO_2	·20	·65	·60	3·70	2·20	1·75
ZrO_2	trace	...	...	...	...	...
P_2O_5	·28	·16	·38	·80	·65	·61
SO_3	trace	trace	·25	·32	·05	trace
Cl	·03	minute trace	faint trace	·03	·02	·02
Fl	...	·05	·15	...	...	...
[2]S (soluble)	·05	·09	·02	·10	trace	·20
Cr_2O_3	nil	nil	nil	·02	·11	·21
NiCoO	...	...	...	...	trace	trace
MnO	·49	·42	·47	·32	·48	·18
BaO	nil	trace	trace	·24	trace	nil
SrO	nil	nil	nil	trace	nil	nil
Li_2O	trace	trace	trace	nil	nil	nil
V_2O_5	nil	nil	nil	·02	trace	trace
	100·43	100·42	100·08	100·41	99·81	99·96
	·02	·03	·07	·05		·10
Total	100·41	100·39	100·01	100·36	99·81	99·86
Sp. Gr.	2·618	2·706	2 675	2·801	2·995	2·891

Legend.

I. Trachyte from the trigonometrical station on top of Mount Jellore.
II. Melanocratic Gib syenite from Loveridge's Quarry.
III. Leucocratic Gib syenite from Saunder's Quarry.
IV. Essexite from Jellore Creek near the junction with Powell's Creek.
V. Basalt from the capping on "Woodlands."
VI. Picrite from Jellore Creek, half mile up from junction with Powell's Creek.

[1] Cross, Iddings, Pirrson—Washington. "Quantitative classification of igneous rocks."

[2] This represents both sulphides and soluble sulphates; and as pyrites can be distinguished in most of the specimens, this sulphur has been calculated as sulphide.

ing the rocks of the Mittagong district. To this end analyses have been made of the more typical igneous rocks, and magmatic names assigned. The blue hornblende mentioned as occurring in the Gib syenite and in the trachyte of Mount Jellore has been carefully examined, and found to be allied most nearly to arfvedsonite. It is practically a silicate of iron and the alkalies, and it is noteworthy that it contains ·75% of titanic oxide and ·6% lithium oxide. The "norms" are set forth below, for comparison with the actual mineral composition noted under Section IV.

I. *Jellore Trachyte.*—This specimen was taken from the very top of Mount Jellore close to the trigonometrical station. It has a slight greenish appearance in the hand specimen due to decomposition of the hornblende.

Composition of the "norm":—

Quartz	...	12·42	Ilmenite	...	·46
Orthoclase	...	23·91	Pyrite...	...	·10
Albite ...	...	51·35	Apatite	...	·67
Anorthite	...	·56	Water ...	...	1·21
Diopside	...	6·23			
Hypersthene ...		·26			100·42
Magnetite	...	3·25			

The chief difference between the norm and the mode here is that instead of diopside the rock contains aegirine and arfvedsonite.

Classification.—Class I., Order 4, Rang 2, Subrang 3.

Magmatic name.—Toscanose.

II. *Melanocratic Gib Syenite.*—This specimen probably represents the more central portion of the Gib rock syenite, and is distinguished from the light variety by having a higher silica percentage, and containing a considerable amount of magnetite which is absent in the latter.

Composition of the "norm":—

Orthoclase ...	55·04	Pyrite	·10
Albite	20·44	Apatite ...	·34
Anorthite ...	3·06	Fluorite ...	·07
Diopside ...	5·51	Carbon dioxide	1·80
Hypersthene ...	3·40	Water	1·20
Olivine ...	1·33		
Magnetite ...	7·19		100·70
Ilmenite ...	1·22		

In order to obtain the "mode" a rearrangement of the diopside, hypersthene, and olivine molecules to form aegirine and arfvedsonite would be required.

Classification.—Class II., Order 5, Rang 2, Subrang 2.

Magmatic name.—Ciminose.

III. *Leucocratic Gib Syenite.*—This rock represents the marginal portions of the Gib rock syenite. The specimen was obtained from Saunders' Quarry, which is about 100 yards from the junction with the sedimentary rocks, where the sandstone has been converted into a glassy quartzite.

Composition of the "norm":—

Orthoclase ...	40·03	Apatite ...	1·34
Albite	25·15	Fluorite ...	·23
Noselite ...	2·13	Carbon dioxide	1·50
Nephelite ...	5·40	Water	1·73
Acmite ...	6·47		
Diopside ...	6·17		99·84
Olivine ...	8·47		
Ilmenite ...	1·22		

The presence of a small percentage of nephelite and noselite indicated by the norm, is not confirmed by microscopical investigation and so together with the diopside and olivine would have to be molecularly rearranged to the production of aegirine and arfvedsonite in the mode.

Classification.—Class II., Order 6, Rang 2, Subrang 3.

Magmatic name.—Borolanose.

IV. *Essexite.*—The specimen was obtained at Jellore Creek near the foot of Mount Jellore from the upper portion of the intrusive dolerite sheet. The rock showed abundant large plates of ilmenite, and although macroscopically apparently fresh, was evidently partly decomposed from the large percentage of calcite which appeared in the microscope section.

Composition of the "norm":—

Quartz ...	11·94	Chromite ...	·22
Orthoclase ...	10·56	Pyrite	·10
Albite	20·96	Apatite ...	2·02
Anorthite ...	6·67	Calcite ...	10·20
Nephelite ...	3·84	Vanadic oxide	·18
Diopside ...	10·63	Water	3·24
Hypersthene ...	6·35		
Magnetite ...	6·96		100·86
Ilmenite ...	6·99		

In this case the norm is very different to the mode; the quartz, nephelite, diopside, and hypersthene of the former representing augite and biotite of the rock.

Classification.—Owing to the advanced state of decomposition it is not possible to classify this rock correctly.

V. *Basalt.*—This basalt obtained from the capping on "Woodlands" was analysed as being typical of the numerous flows of the district. The specific gravities of a number of these basalts showed this particular specimen to be very slightly heavier than the average.

Composition of the "norm":—

Orthoclase ...	6·12	Ilmenite ...	4·26
Albite	15·72	Apatite ...	1·34
Anorthite ...	29·19	Water	2·60
Nephelite ...	5·11		
Diopside ...	7·91		100·26
Olivine ...	24·76		
Magnetite ...	3·25		

The minerals orthoclase, nephelite, and diopside appearing in the norm are absent in the rock. In order to form the mode they would have to be molecularly re-arranged to the production of pyroxene.

Classification.—Class III., Order 5, Rang 4, Subrang 3.

Magmatic name.—Auvergnose.

VI. *Picrite.*—This rock was obtained from Jellore Creek at the spot indicated on the map. The specific gravities of a number of fragments of the rock taken from this outcrop show that the specimen analysed is not so basic as some of the other specimens, but is of fair average composition. The rock was in an advanced state of serpentinisation which accounts for the large amount of combined water.

Composition of the "norm":—

Orthoclase ...	3·34%	Pyrite... ...	·36%
Albite	11·00	Apatite ...	1·34
Anorthite ...	27·52	Chromite ...	·24
Hypersthene ...	26·58	Carbon dioxide	·40
Olivine ...	7·86	Water	7·40
Magnetite ...	9·51		
Corundum ...	·71		99·60%
Ilmenite ...	3·34		

The norm differs from the mode in the rearrangement of its orthoclase, and hypersthene molecules to form augite and olivine of the rock.

Classification.—Class III., Order 5, Rang 4, Subrang 3.

Magmatic name.—Auvergnose.

VI. Age.

It is unfortunate that in the eastern portion of New South Wales, there are no well developed sedimentary deposits of later date than the Trias. The area occupied by the Bue Mountains would appear to have been a land surface since that period. Hence it is a matter of extreme

difficulty to fix the age of many eruptive rocks in this division of the State further than to classify them as Post Triassic. We cannot depend therefore on palæontological data, but must rely on uncertain evidence, such as the amount of erosion, petrological resemblance, and tectonic position. It is preferable to deal with the subject under two heads—(*a*) Relative age (*b*) Absolute age.

(*a*) The syenites and trachytes representing the more acid rocks of the district intrude the permo-carboniferous and triassic sedimentary deposits, tilting them up at considerable angles. The dolerite sills of the Nattai River and Jellore Creek intrude the coal measures and send off large dykes which intersect the Triassic sedimentary rocks. A fault occurs in Jellore Creek which seems to be connected with the effusion of the trachytes of Mount Jellore; the dolerites here intrude the coal measures only on one side of the fault which seems to be conclusive evidence that these rocks were intruded at a date subsequent to the faulting of the sedimentary formations; this faulting being supposed to be due to the intrusion of the intermediate igneous rocks. Another minor point of evidence is that the field occurrence of the basic rock makes them parasitical on the masses of the Gib and Mount Jellore.

The connection between the basalts and dolerites is more obscure, but there is strong evidence to prove that the basalt flows are subsequent to the dolerite intrusions.

The basalts are in the form of approximately horizontal flows, and are found overlying gravel beds in some cases containing pebbles of an older basalt; in turn these gravel beds overlie the eroded surface of tilted Wianamatta shales. The flows being approximately horizontal is proof that very little earth movement has taken place since the time of their formation, and their mode of occurrence in cappings on the tilted shales proves them to be the production of

later volcanic activity than that causing this tilting. Thus an interesting sequence can be traced in these rocks, the more acid forming the earliest intrusions, the basic rocks following afterwards.

(*b*) Under the preceding subdivision the earlier igneous rocks are shewn to be Post Triassic. The basalt flows which represent the latest members of the series were described as overlying pebble drift beds, the age of which although not very exactly determined, has been shown to be later than early Tertiary, by leaf remains found in a similar bed at Wingello. These basalts are homotaxial with the pliocene basaltic flows extensively developed at Gulgong, and other parts of New South Wales.

The syenites and trachytes of this district bear an intimate relationship to similar rocks of the Glass House Mountains in Queensland, the Warrumbungle Mountains in New South Wales, and the soda series of Mount Macedon in Victoria, and as there is good evidence[1] to show that these allied rocks are Cretaceous or Cretaceo-Eocene. It is probable that the Mittagong intermediate rocks which are known to be Post Triassic are of the same age, viz., late Cretaceous or early Eocene.

VII. SUMMARY.

A regular sequence of igneous rocks beginning in Cretaceous times and extending till late Tertiary has taken place in the Mittagong district. The intrusion and effusion of the molten magmas was accompanied by faulting and fissuring of the sedimentary beds, leading to the production of bosses, lavas, sills and dykes. The trachytes of this district, like those already mentioned homotaxial with them, are remarkable for their high percentage of alkalies, and

[1] T. W. E. David, B.A., F.R.S., "Note on the occurrence of diatomaceous earth at the Warrumbungle Mountains New South Wales." Proc. Linn. Soc. N.S.W., June 1896.

in containing a blue hornblende allied to arfvedsonite. The main point of distinction being that the Mittagong variety is more even grained and compact.

There has been much speculation by geologists of this State as to the relations of the igneous magmas, and their positions in the Permo-Carboniferous coal basin of eastern New South Wales. Much work[1] has already been done in this connection, chiefly by the Geological Survey Department, and it is hoped that this paper will form one more link in the chain of evidence needed, before evidence is no longer supposititious, and theories become facts.

The igneous rocks of the Mittagong district form only one example of volcanic activity subsequent to the deposition of the sedimentary rocks in this coal basin. Many more have already been described, chiefly constituting extensive flows of basalt and associated dykes met with over a large portion of the area.

Attention has already been drawn to the fact that the more acid rocks seem to lie nearer the periphery, basic rocks occupying the central portions. How far this is true can only be ascertained by analyses of a large number of rocks, but in the case of the area dealt with in this paper, this seems to be true, as its intermediate rocks hold a position relatively near the shores of this old lake basin.

A bulletin[2] of the Geological Survey Department recently published dealing with the geology of the Cambewarra Ranges, is of immense importance as affording most valuable evidence of volcanic activity contemporaneous with the sedimentation in the Permo-Carbonaceous coal basin already referred to. Here it is shown that flows of trachyte and associated tuffs constitute a thickness of about 1,000

[1] Records of Geological Survey of N.S.W., Vol. VII., part ii., 1902, p. 93; part iii., 1902, p. 226; part iii., 1903, p. 236.

[2] Ibid., pp. 103 - 140.

feet between the top of the upper marine and the bottom of the Newcastle Bulli coal measures; this outburst was followed in regular sequence by basaltic flows above the coal measures.

Much more data is at hand to prove that volcanic activity was contemporaneous with sedimentation over this subsidence area, as for example the Kiama volcanic series, the chocolate and purple shales of the Narrabeen series etc. Further evidence which has perhaps hitherto been overlooked is the occurrence of foreign pebbles of igneous rocks in the old denuded volcanic pipes of which that at Pennant Hills and at "the basin" on the Nepean are examples. Differentiation in the lower portions of the neck and subsequent tearing off and floating up of the fragments cannot be ascribed as the origin of all these varieties[1] of included fragments. A good example is that of a large fragment, over one inch in length of orthoclase found in the basalt over the Bowral railway tunnel.[2] It would appear then, that the sediments in this area of subsidence form an immense thickness of rock, which like a mighty tomb has buried within it, tier upon tier, the ruins of once active volcanoes, but whose only memory now is an occasional thin bed of lava or a belt of purple shales hardly recognisable as being of volcanic origin.

In conclusion we desire to thank Mr. E. C. Larkin of Fitzroy Iron Works for his hospitality during our numerous visits, and Mr. G. Saunders for aid in field work on the last visit, and to express our gratitude to Professor David and Mr. H. Jevons B.Sc., for help on every occasion where help was necessary.

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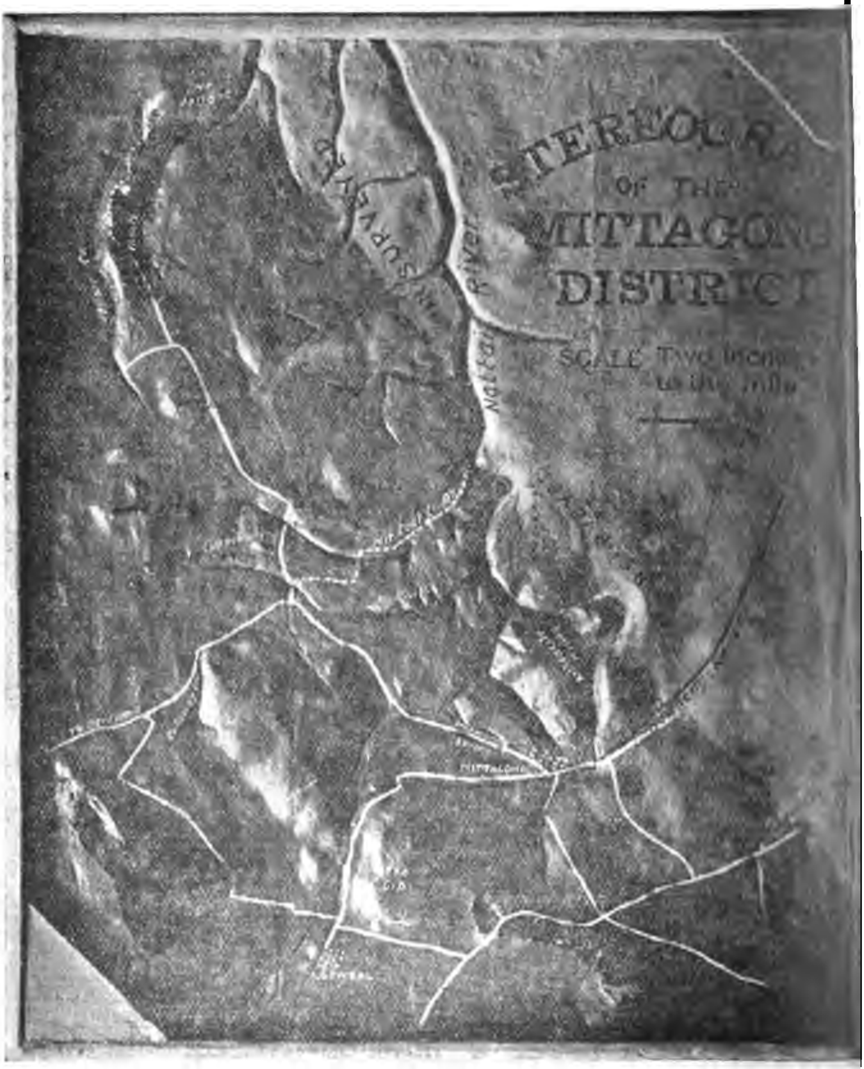
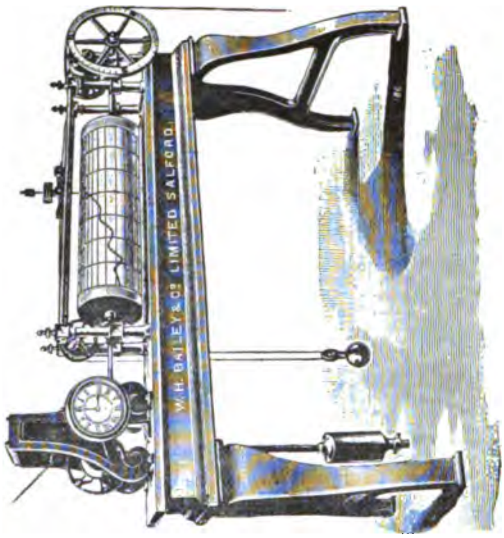
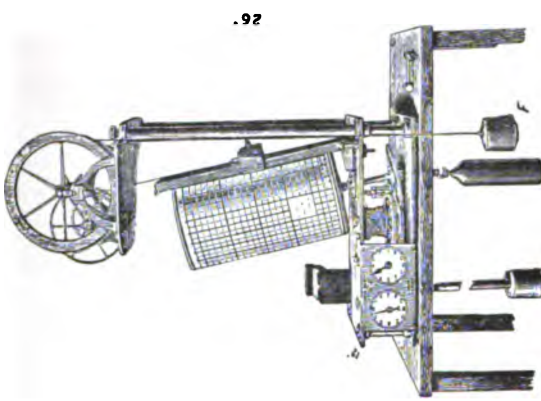
[1] Some of these are more acid than the enclosing lava.

[2] Vide antea page (325).

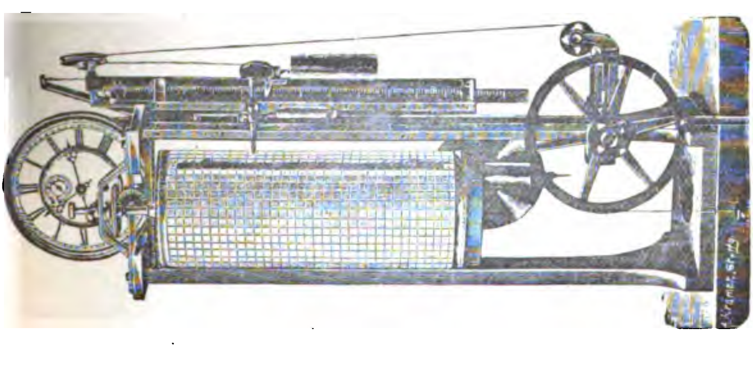

OF THE
SCALE
River



BAILEY'S GAUGE



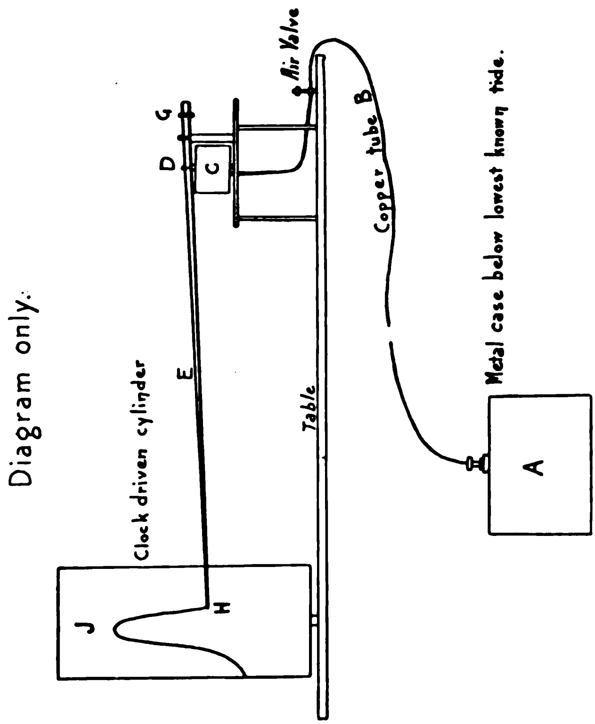
LORD KELVIN'S GAUGE



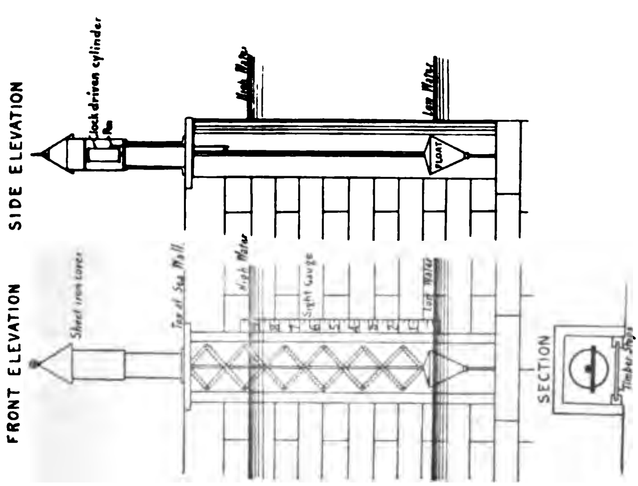
GERMAN GAUGE

RICHARD GAUGE

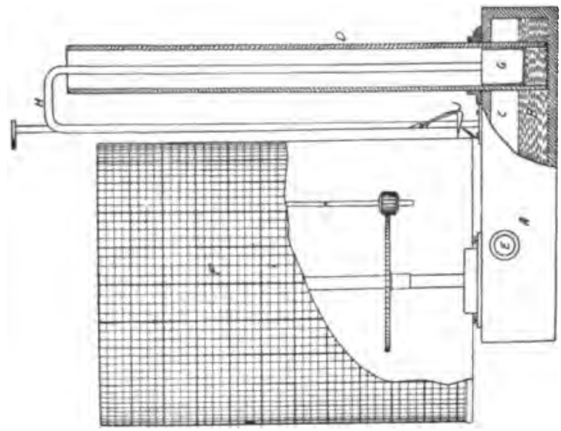
Diagram only.

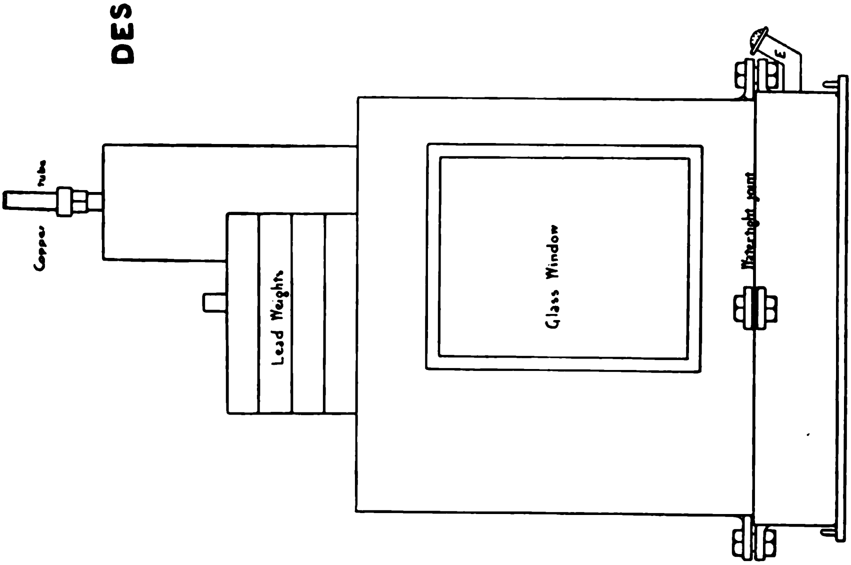


LAZY TONGS GAUGE

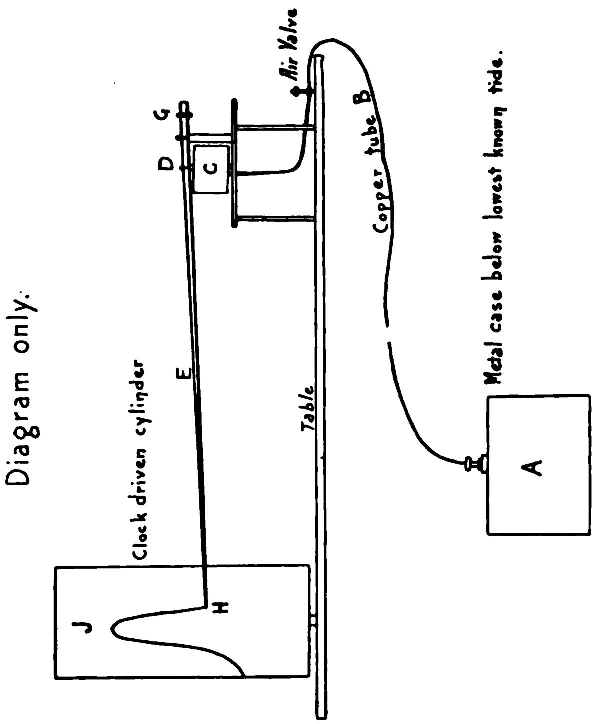


DESICN FOR TIDE CAUCE

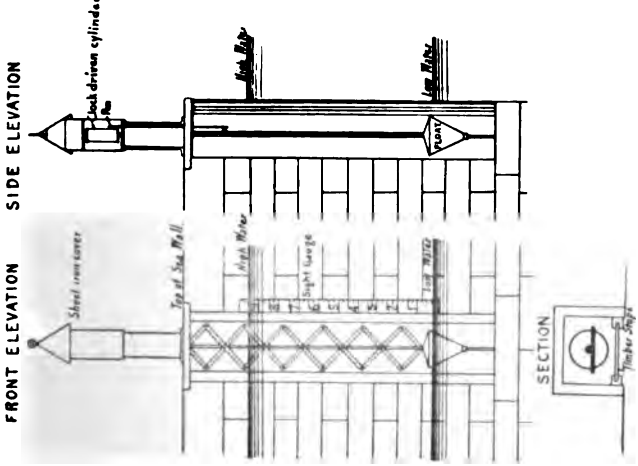




RICHARD GAUGE

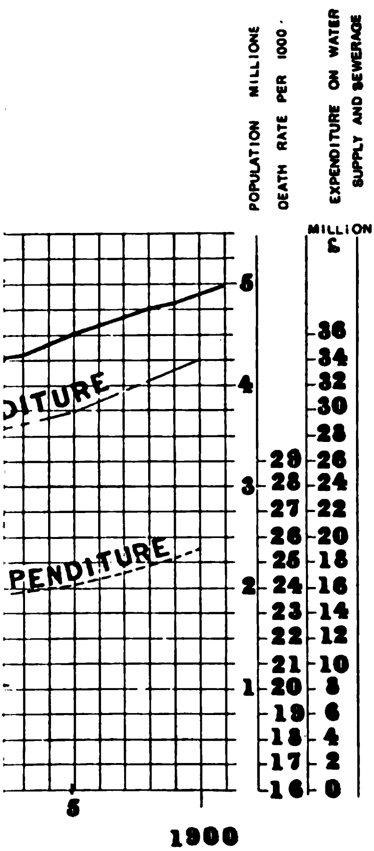


LAZY TONGS GAUGE



ITARY WORKS

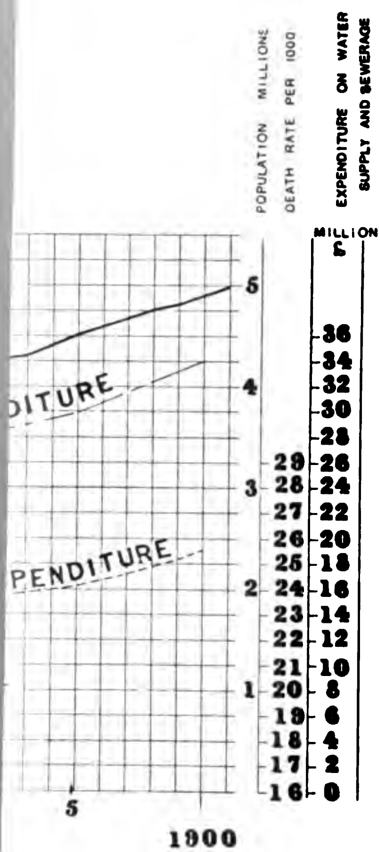
UPPLY & SEWERAGE.



Reduced ½. The numerals refer to the pits. I.—1 1/16" x 1⅜" deep. II.—1¼" x 1¼" deep. III.—2" x 1⅜" deep. IV.—4⅜" x 2¾" deep. V.—⅞" x ½" deep. VI.—3" x ¾" deep.

ITARY WORKS

UPPLY & SEWERAGE.



The Narraburra Siderite, N.S.W.

End view. Reduced to $\frac{1}{3}$. VIII.—$3\frac{1}{2}''$ x 2 x $1\frac{1}{2}''$ deep. IX.—$3''$ x $1''$ deep. X.—$2\frac{1}{2}''$ x $\frac{3}{4}''$ deep. XI.—$3''$ x $\frac{1}{2}''$ deep. XII.—$1''$ x $\frac{1}{2}''$. XIII.—$2\frac{1}{2}''$ x $\frac{3}{8}''$. XIV.—$\frac{3}{4}''$ x $\frac{3}{8}''$.

b

a

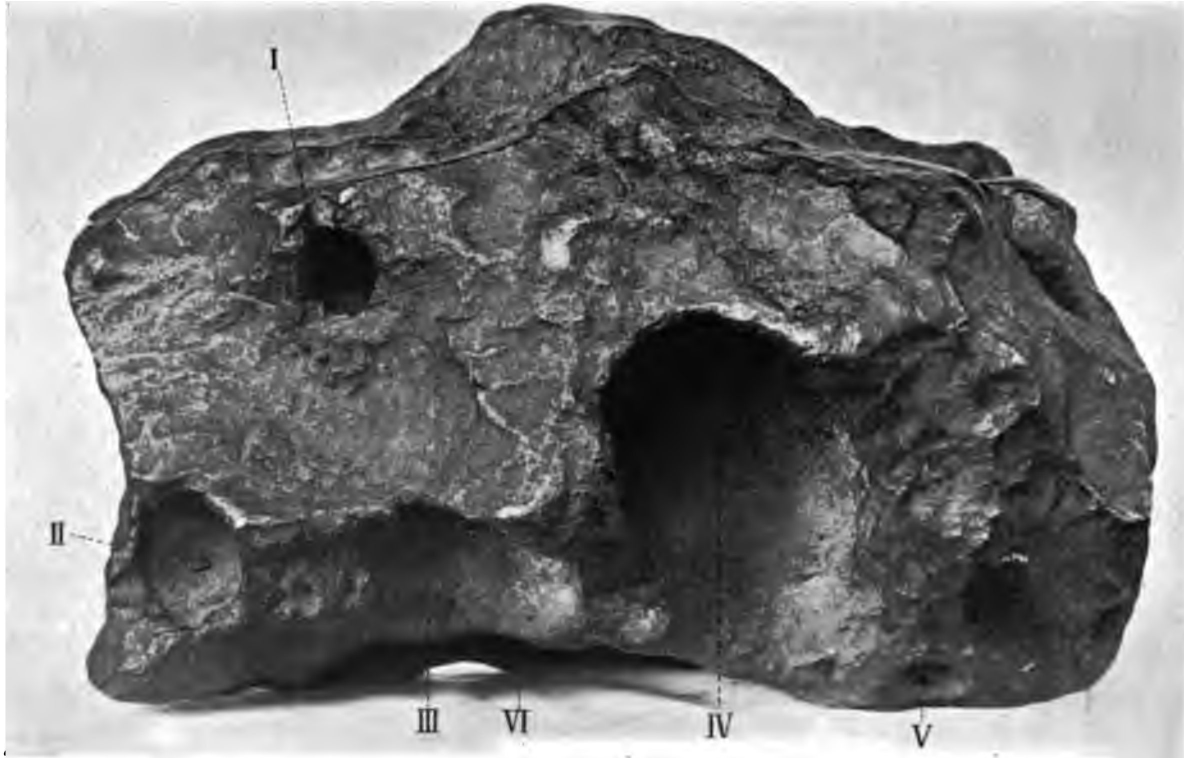
a b

Section 8. ¼ nat. size. Etched by bromine water.

The Narraburra Siderite, N.S.W.

Section 8. The part between *a* and *b* of Plate XIII. Enlarged 2 dias.

Journal Royal Society of N.S.W., Vol. XXXVII., 1903. *Plate XI.*



Reduced $\frac{1}{2}$. The numerals refer to the pits. I.—$1\frac{1}{16}$″ x $1\frac{3}{8}$″ deep. II.—$1\frac{1}{4}$″ x $1\frac{1}{4}$″ deep. III.—2″ x $1\frac{1}{8}$″ deep. IV. – $4\frac{1}{2}$″ x $2\frac{1}{4}$″ deep. V.—$\frac{3}{4}$″ x $\frac{1}{2}$″ deep. VI.—3″ x $\frac{3}{4}$″ deep.

Journal Royal Society of N.S.W., Vol. XXXVII., 1903. *Plate XII.*

End view. Reduced to ⅓. VIII.—3½" x 2 x 1½" deep. IX.—3" x 1" deep. X.—2¼" x ¾" deep. XI.—3" x ½" deep. XII.—1" x ½". XIII.—2½" x ⅛". XIV.—¾" x ⅜".

Journal Royal Society of N.S.W., Vol. XXXVII., 1903. *Plate XIII.*

b

a

The Narraburra Siderite, N.S.W.

a b

Section 8. ½ nat. size. Etched by bromine water.

Section 8. The part between *a* and *b* of Plate XIII. Enlarged 2 dias.

The Narraburra Siderite, N.S.W.

Section 7. ½ nat. size.

Section 6. Reduced $\frac{13}{20}$

The Narraburra Siderite, N.S.W.

Section 5. Reduced $\frac{12}{16}$

The Narraburra Siderite, N.S.W.

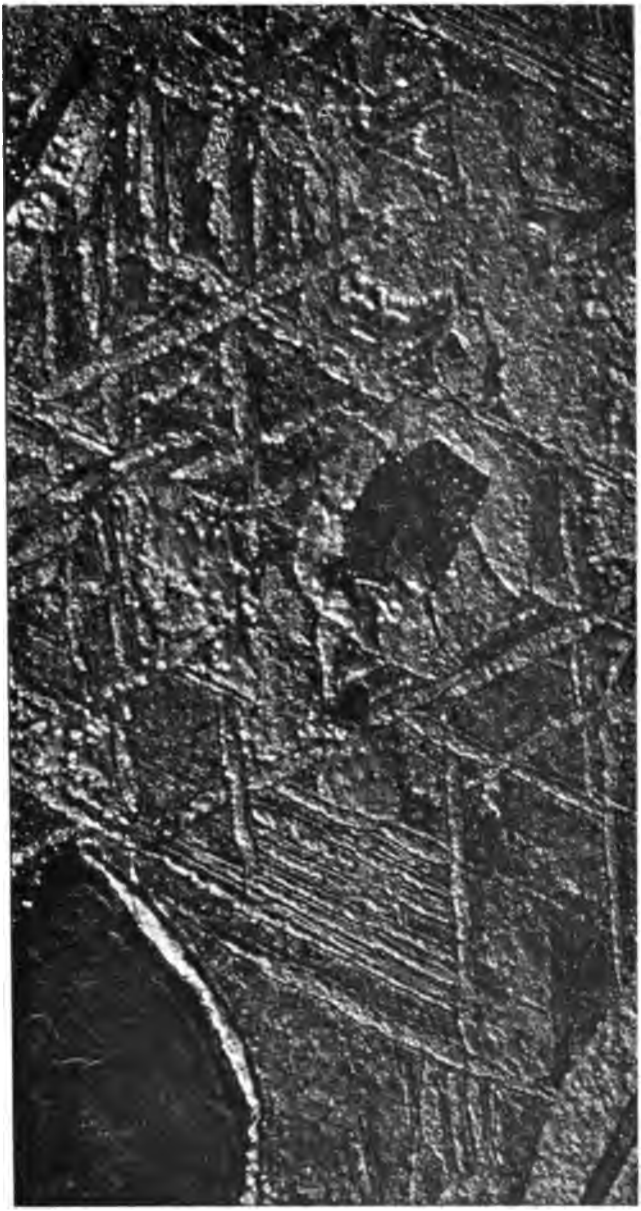
Section 4. Reduced $\frac{13}{17}$

The Narraburra Siderite, N.S.W.

Section 3. Nat. Size. Etched by $CuSO_4$ sol.

Journal Royal Society of N.S.W., Vol. XXXVII., 1903. *Plate XX.*

The Narraburra Siderite, N.S.W.



Part of Section 3, at *a* enlarged 5 dias.

The Narraburra Siderite, N.S.W.

Section 2. Enlarged 1⅓ dias.

Section 1. Enlarged 2 dias. Etched by bromine water.

Journal Royal Society N.S.Wales. Vol. XXXVII 1903. Plate XXIII

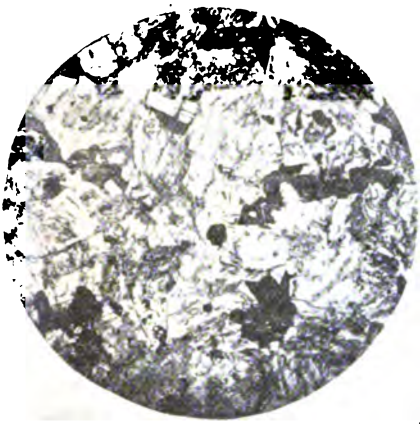


Fig. 1.

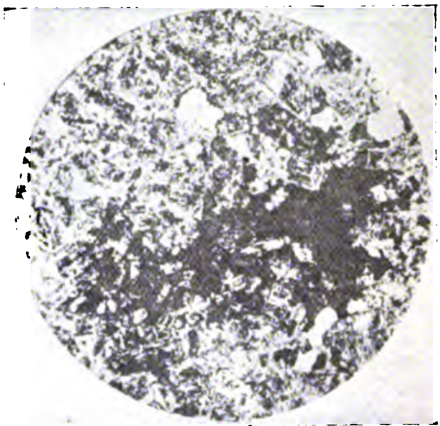


Fig. 2.

Fig. 3.

Fig. 4.

ABSTRACT OF PROCEEDINGS

a—May 6, 1903.

ABSTRACT OF PROCEEDINGS

OF THE

Royal Society of New South Wales.

ABSTRACT OF PROCEEDINGS, MAY 6, 1903.

The Annual General Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, May 6th, 1903.

Prof. WARREN, M. Inst. C.E., Wh. Sc., President, in the Chair.

Forty-two members and five visitors were present.

The minutes of the preceding meeting were read and confirmed.

The following Financial Statement for the year ended 31st March, 1903, was presented by the Hon. Treasurer, and adopted:—

GENERAL ACCOUNT.

Receipts.	£	s.	d.	£	s.	d.
Subscriptions — One Guinea	82	19	0			
Subscriptions — Two Guineas	354	18	0			
Subscriptions — Arrears	80	12	0			
Subscriptions — Advances	8	8	0			
				526	17	0
Parliamentary Grant on Subscriptions received—						
Vote for 1902-1903	500	0	0			
				500	0	0
Rent...				46	5	0
Sundries				14	8	9
Clarke Memorial Fund				300	0	0
Composition for Life Membership				21	0	0
Total Receipts				1408	10	9
Balance on 1st April, 1902				59	9	1
				£1467	19	10

Payments.	£ s. d.	£ s. d.
Advertisements	25 0 6	
Assistant Secretary	250 0 0	
Books and Periodicals	92 5 7	
Bookbinding	2 10 6	
Conversazione	55 16 5	
Collector	3 15 7	
Expenses at Meetings	28 3 0	
Freight, Charges, Packing, &c....	6 14 4	
Furniture and Effects	12 12 2	
Gas	17 18 1	
Housekeeper	10 0 0	
Insurance	9 8 0	
Interest on Mortgage	56 0 0	
Office Boy	24 5 4	
Petty Cash Expenses	10 18 8	
Postage and Duty Stamps	32 7 6	
Printing	34 10 6	
Printing and Publishing Journal	307 2 6	
Printing Extra Copies of Papers	19 6 6	
Rates (including Water and Sewerage Rates to 30th June, 1903)	57 15 0	
Reception	2 1 3	
Repairs	47 16 0	
Stationery	24 9 3	
Sundries	27 6 0	
Total Payments		1158 2 8
Repayment to Clarke Memorial Fund... ...		300 0 0
Bank Charges		0 17 6
Balance on 31st March, 1903, viz.:—		
Cash in hand...	10 0 0	
Less Overdraft, Union Bank	1 0 4	
		8 19 8
		£1467 19 10

BUILDING AND INVESTMENT FUND.

Receipts.	£ s. d.
Loan on Mortgage at 4%	1400 0 0
	£1400 0 0

Payments.	£ s. d.
Advance to General Account 31st March, 1897	8 0 6
Balance 31st March, 1903	1391 19 6
	£1400 0 0

CLARKE MEMORIAL FUND.

Receipts.	£	s.	d.
Amount of Fund, 31st March, 1902	444	11	0
Interest to 31st March, 1903	9	14	3
	£454	5	3

	£	s.	d.
Deposit in Savings Bank of New South Wales, March 31, 1903	224	9	6
Deposit in Government Savings Bank, March 31, 1903 ...	229	15	9
	£454	5	3

AUDITED AND FOUND CORRECT, AS CONTAINED IN THE BOOKS OF ACCOUNTS.

DAVID FELL, C.A.A. .... }
J. TYNDALL PETERSON, A.S.I.A. } *Honorary Auditors.*

SYDNEY, 24th April, 1903.

D. CARMENT, F.I.A., F.F.A. *Honorary Treasurer.*
W. H. WEBB, *Assistant Secretary.*

A vote of thanks was passed to the Hon. Auditors, viz., Mr. DAVID FELL, C.A.A., and Mr. T. TYNDALL PETERSON, A.S.I.A., for their services.

There being no other nominations the following gentlemen were elected officers and members of Council for the current year:—

President:

F. B. GUTHRIE, F.I.C., F.C.S.

Vice-Presidents:

H. C. RUSSELL, B.A., C.M.G., F.R.S.	Prof. LIVERSIDGE, LL.D., F.R.S.
W. M. HAMLET, F.I.C., F.C.S.	Prof. WARREN, M. Inst. C.E., Wh.Sc.

Hon. Treasurer:

D. CARMENT, F.I.A., F.F.A.

Hon. Secretaries:

J. H. MAIDEN, F.L.S.	G. H. KNIBBS, F.R.A.S.

Members of Council:

S. H. BARRACLOUGH, B.E., M.M.E.	F. H. QUAIFE, M.A., M.D.
C. O. BURGE, M. Inst. C.E.	GEORGE E. RENNIE, B.A., M.D.
Prof. T. W. E. DAVID, B.A., F.R.S.	HENRY G. SMITH, F.C.S.
HENRY DEANE, M.A., M. Inst. C.E.	WALTER SPENCER, M.D.
CHARLES MOORE, F.R.B.S.	J. STUART THOM

The certificate of one candidate was read for the second time, and of nine for the first time.

The following announcements were made:—

1. That the Council recommended the election of the following gentlemen as Honorary Members of the Society, viz.:—

   Rt. Hon. LORD KELVIN, G.C.V.O., D.C.L., LL.D., F.R.S., &c.

   Rt. Hon. LORD LISTER, O.M., F.R.C.S., D.C.L., LL.D., F.R.S., &c.

The election was carried unanimously. It was likewise announced that the Council had also recommended the election of Sir GEORGE GABRIEL STOKES, Bart, M.A., D.C.L., LL.D., F.R.S., etc., but that that distinguished man had recently died.

2. That the Council had awarded the Clarke Memorial Medal to F. MANSON BAILEY, F.L.S., Colonial Botanist of Queensland.

3. That the Society's Journal for 1902 was in the hands of the binder and would be delivered to members shortly. Advance copies were laid upon the table.

One hundred and one volumes, 642 parts, 117 reports, 119 pamphlets, and 5 chronographical tables, total 984, received as donations since the last meeting were laid upon the table and acknowledged.

The following letters were read:—

Office of Colonial Botanist,
Brisbane, 19th December, 1902.

To the President and Council of the Royal Society of N.S. Wales.

Gentlemen,—I have very great pleasure in acknowledging the receipt of your letter and the accompanying medal. You have conferred upon me a very great honor in presenting me with the Clarke Medal, and I feel at a loss for words to sufficiently thank you for paying me so great a compliment.

Yours very truly,
F. MANSON BAILEY.

Commonwealth of Australia, Governor-General,
Government House, Sydney, 8th April, 1903.

Sir,—I have the honour, by direction of His Excellency the Governor-General, to acknowledge the receipt of your letter of 7th inst. His Excellency feels greatly honoured by the request of your Council that he should become Patron of your Society, and has much pleasure in accepting that position.

I have the honour to be Sir, your obedient servant,
J. N. E. WINGFIELD,
Private Secretary to His Excellency the Governor-General.

The Hon. Secretary, Royal Society of N. S. Wales.

Professor WARREN, M. Inst. C.E., Wh. Sc., then read his address, previously, however, making the following remarks relating to the affairs of the Society.

Financial Position.—The expenses incurred during the year have been rather heavier than usual, chiefly in regard to the cost of publishing the Journal and repairs to the premises; the Hon. Treasurer has however been able to pay his way and to carry forward a balance of £8 19s. 8d.

The Library.—The sum spent during the year upon books and periodicals was £92 5s. 7d.

Exchanges.—Last year the Society exchanged its Journal and Proceedings with 426 kindred Institutions, the following having been added to the list:—Musée Nacional de Buenos Aires; Deutsches Meteorologisches Gesellschaft, Aachen; Instituto Geologico de Mexico; Naturforschende Gesellschaft, Basel; American Microscopical Society, Lincoln, Nebr.; and in return it has received 289 volumes, 1,511 parts, 136 reports, 174 pamphlets, 1 hydrographic and 2 meteorological charts, total 2,113.

Papers read in 1902.—During the past year the Society held eight (8) meetings at which 17 papers were read; the average attendance of members was 50 and of visitors 3.

Sections.—The *Economic Science Section* held five meetings at which five papers were read and discussed.

The *Engineering Section* held five meetings at which three papers were read and discussed. The average attendance of members and visitors was 20.

I would like to draw the attention of members to the arrangements made by the Engineering Section for this year's meetings. In place of holding the customary monthly meeting, at which one, or at most two papers would be read, it has been decided to hold *two* or possibly *three Sessions* at intervals of a couple of months. Each Session will extend over *two nights* at least, and only one general topic will be considered at each Session, a number of papers on different aspects of the same subject being presented for discussion. The first of these Sessions will be devoted to the question of *Water Conservation*, and the second to the problem of *Technical and Industrial Education in Australia*. Already a large number of papers have been promised, and there is every prospect of the new departure producing very valuable results.

Lectures.—A course of five science lectures was delivered during the Session, and were well attended.

Conversazione.—A very successful Conversazione was held in the Great Hall of the University, on Friday, December 5th, 1902.

Roll of Members.—The number of members on the Roll on the 30th April, 1902 was 375. During the past year 14 new members were elected; the deaths numbered 9, resignations 20, and 16 were struck off the Roll for non-payment of their subscriptions, leaving a total of 344 to date.

Obituary.—The following is a list of members who have died during the year:—

James Comrie; elected 1856.
J. J. Farr; elected 1889.
Dr. A. M. Megginson; elected 1888.

Dr. F. Milford; elected 1873.
James Milson; elected 1882.
Sydney Moss; elected 1882.
Joseph Thompson; elected 1875.
Dr. G. A. Tucker; elected 1877.
Rev. Dr. James S. White; elected 1874.

THE DEVELOPMENT AND PROGRESS OF ENGINEERING DURING THE LAST TWENTY-ONE YEARS.

In steam engineering the finest examples of modern steam engines to-day are to be seen in the mail steamers which run from New York to Great Britain and Europe, and also in the large power plants of America and Europe, where they are arranged to drive electrical generators. Various examples of modern engines were briefly described. The use of steam jackets, re-heaters, and superheating apparatus for reduction of cylinder condensation was briefly referred to, also the modern tendency in the use of auxiliary engines, large units, economisers in the flues, high chimneys, automatic stokers supplied with coal handling machinery. By far the most important improvement of recent years in steam engineering is the development of the steam turbine, which is chiefly due to the Hon. C. A. Parsons. The chronology of the turbine was referred to, and the tendency of modern development in simplicity, steam economy and speed. The advantages of steam turbines over reciprocating engines was fully considered. The steam engine has through nearly two centuries of continued improvement reached the zenith of its career of usefulness, and is in danger of displacement by either one or both of its two thermodynamic superiors, the steam turbine and the gas engine.

Steam Boilers.—Recent progress in this branch was referred to, and the tendency in the use of water tube boilers both on land and at sea. The advantages in the use of oil fuel were briefly considered.

Electrical Engineering is concerned mainly with the generation, transmission, and distribution of electricity for lighting and power purposes. The various systems of electric traction were briefly described and the system at present in operation in Sydney was referred to in considerable detail. The development of water power in various parts of the world and the improvements of water turbines were dealt with and typical cases were described in detail. The electrical distribution of power in industrial establishments was compared with ordinary shafting and belting, and the methods of controlling the speed in electrical motors was briefly explained.

Bridge Building—The various causes were explained which have contributed to the development of the art of the bridge builder, and its position to-day. There is no branch of engineering where science and experience has been so completely united, or where greater success has been achieved in economy of material, manufacture and efficiency; in support of this statement many examples were given including the great Forth Bridge, and the designs of the English, American, and German Engineers for the proposed Sydney Harbour Bridge. The design and construction of foundations were next considered with especial reference to the pneumatic and freezing processes. The testing of the materials of construction was considered in regard to its influence on engineering construction, and to the work of the International Society for testing materials, and the Congress held in Paris in 1900. Reference was also made to the various investigations and original researches made in the P. N. Russell Laboratory, University of Sydney.

Irrigation.—The beneficial effects of the application of water to arid soil was next dealt with, and examples of successful irrigation in various parts of the world were

briefly referred to. The proposed expenditure on water conservation works in New South Wales was discussed in considerable detail. Harbour works in New South Wales were referred to, and the main principle adopted, namely, concentrated tidal scour, for maintaining and permanently improving river entrances; a list was given of the works accomplished during the last ten years.

Sewerage Systems.—The advantages and disadvantages of the so-called combined and separate systems were summarized, and the use of the septic-tank as an adjunct to some of the various methods adopted in sewage disposal.

New South Wales Government Railways.—The most important works carried out in connection with the Permanent Way Department of the Railways may be summarized as comprising improvements of grades and curves, duplicating existing lines, strengthening of existing lines and bridges, providing new buildings, and water supplies. These were dealt with in detail, and also the improvements made in the design of locomotives to meet the special needs of the traffic on the N. S. Wales railways.

The author has endeavoured to indicate in this address some of the achievements of the engineer during the last twenty years. The wonderful progress during that time, and the great activity to-day in all branches of science and engineering suggests gigantic possibilities in the future. All future progress in engineering must depend upon exact knowledge and scientific thought and work. Our systems of primary, secondary, technical and professional education must be carefully reconsidered in order to bring them up to the needs and requirements of modern civilization. The engineer of the future must be a still more widely trained and better educated man than his predecessor of to-day, so that he may be better able to solve the many problems which lie before him in the future. The President then

brought to a close by thanking the Society for their patient attention, and in vacating the Chair in favour of Mr. F. B. Guthrie, the newly elected President, asked them to give him the same support which has always been accorded to the speaker.

A vote of thanks was passed to the retiring President, and Mr. F. B. GUTHRIE, F.I.C., F.C.S., was installed as President for the ensuing year.

Mr. GUTHRIE thanked the members for the honour conferred upon him and made the following announcements:—

1. That the series of popular Science Lectures would continue to be delivered at the Society's House on the fourth Thursday in each month at 8 p.m., as follows:—

May 28th—"*The Development of the Railway*,"(Illustrated by Lantern-slides) by C. O. BURGE, M. Inst. C.E.

June 25th—"*The Australian Flora*," by R. T. Baker, F.L.S., Curator, Technological Museum.

July 23rd—"*Ancient Italian Life*," (Illustrated by lantern slides prepared from objects in the Nicholson Museum of Antiquities, Sydney University) by F. LLOYD, B.A., LL.B., Assistant Lecturer in Latin and Curator of the Nicholson Museum.

Sept. 24th—"*Some features of Modern Technology*," by G. H. KNIBBS, F.R.A.S., Lecturer in Surveying, Sydney University.

Oct. 22nd—"*Water*," by Prof. LIVERSIDGE, LL.D., F.R.S., etc. This lecture would be delivered in the Chemistry Lecture Theatre at the University.

Nov. 26th—"*The physical characteristics of the Moon*," by Prof. WOODHOUSE, M.A. *Oxon.*, Sydney University.

2. Prof T. W. EDGEWORTH DAVID, F.R.S., etc., would deliver the first of the Clarke Memorial Lectures on Thursday, September 17th, at 8 p.m. Subject:—"*The Life and Work of the Rev. W. B. Clarke.*"

Tickets for all lectures could be obtained by members on application to the Assistant Secretary.

ABSTRACT OF PROCEEDINGS, JUNE 3, 1903.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, June 3rd, 1903.

F. B. GUTHRIE, F.I.C., F.C.S., President, in the Chair.

Thirty members and one visitor were present.

The minutes of the preceding meeting were read and confirmed.

His Honor Judge DOCKER and Mr. J. W. ALLWORTH were appointed Scrutineers, and Mr. HENRY DEANE deputed to preside at the Ballot Box.

The following gentleman was duly elected an ordinary member of the Society:—

Johnston, J. Barre, President Chamber of Commerce, Sydney.

The certificate of one candidate was read for the third time, of nine for the second time, and of two for the first time.

Eleven volumes, 117 parts, 7 reports, and 9 pamphlets, total 144 received as donations since the last meeting were laid upon the table and acknowledged.

THE FOLLOWING PAPERS WERE READ:

1. "Language of the Būngandity Tribe, South Australia," by R. H. MATHEWS, L.S.

Mr. R. H. Mathews, L.S., read a paper on "The Language of the Būngandity Tribe, South Australia," in which he dealt with the grammatical structure of the aboriginal tongues of that State. The article was accompanied by a comprehensive vocabulary of the words most commonly used in ordinary conversation. The author also briefly referred to the social organisation of South Australian tribes from the Lake Eyre basin to Port Lincoln and Mount Gambier.

Remarks were made by Mr. G. H. Knibbs, urging the desirableness of employing the phonetic system, with necessary modifications, of the Association Internationale Phonétique, so as to make permanent the knowledge of the aboriginal language before it was too late, the present system of phonetically rendering it being imperfect. Also by Mr. J. H. Maiden, on the desirableness of exact identification of the plants of which Mr. Mathews gave the aboriginal names. The President made a few remarks and Mr. Mathews replied.

2. "Notes on Tide Gauges, with description of a new one," by G. H. HALLIGAN, F.G.S.

The author gave a brief history of the development of the automatic tide recorders, pointing out the manner in which errors, inseparable from their construction, crept into the records and the difficulty of locating them. The pneumatic gauge was referred to, and the difference between a permanent and a temporary installation of a gauge of this description was illustrated. A new gauge of the author's design was then shown, and its advantages pointed out, and the many troubles met with in the construction of such an instrument were referred to. The cost of the new design (which has not been patented) is about one-fifth of that of the best English, French, and American machines for similar purposes.

Remarks were made by Messrs. C. O. Burge, H. C. Russell, J. H. Maiden, and Percy W. Shaw. Mr. Halligan replied.

EXHIBITS.

Mr. RUSSELL exhibited (1) a series of photographs showing the effect of the recent storm at Cootamundra. (2) A peculiar dendritic figure, which had formed at the bottom of a rain-gauge lately in use on the Hunter River.

Remarks as to the probable cause of this formation were made by Prof. Liversidge.

The following is an abstract of the first Science Lecture of the present Session, delivered on the 28th May, by C. O. BURGE, M. Inst. C.E., on "The Development of the Railway." The introductory portion dealt with the three great epochs of civilisation—Christianity, the Renaissance, and Modern Scientific discovery, and the connection of the two latter through the instrumentality of Francis Bacon, who might be regarded as the father of all modern scientific knowledge though knowing little about it himself. The spirit of inquiry, the induction method, the patient and systematic examination of facts, all the outcome of the Baconian philosophy, were indispensable to scientific progress. The development of railways, one of the most beneficient results of this progress was shown to have chiefly led, in the moral world, to greater toleration of natural differences through greater knowledge, and a contrast was drawn between the contempt and hatred of foreigners existing in England in the pre-railway days, and the more cosmopolitan ideas of the present time. The greater intercourse between the classes nowadays, caused by their meeting more constantly in railway travelling, on more or less equal terms, was also adverted to. Contrasts were then drawn between the conditions of travelling in 1700, 1800, and 1900, and the beginnings of the idea of the railway and the locomotive, in the 17th and 18th centuries, were traced. Solomon de Caus, a Frenchman, was shut up in a mad house in 1641, for proposing to propel a carriage by steam, and anecdotes were given such as that of a country clergyman in 1784, meeting an experimental engine on the highway, which had escaped from its inventor, and his terror at the sight of what he thought was Satan himself; and of Brunton who devised a steam locomotive with legs, which on trial blew up. Trevethick, whose retiring and irresolute temperament prevented his undoubted inventive genius from bearing proper fruit, was the first constructor of a practical

locomotive, and his character was drawn in contrast to to that of George Stephenson, who, later, making use of his ideas, as well as those of Blenkinsop, Hedley, Booth, and others, is universally regarded as the father of railways. His was the common sense, the foresight, the determination, the self-confidence, in the best sense of the word, which brought their inventions to the front, and which, in spite of the most strenuous opposition, finally established the Stockton and Darlington, and Liverpool to Manchester railways, as practicable enterprises. The exciting trial of engines on the latter line in 1829, the victory of the "Rocket," in which Stephenson, as its designer, had embodied the successful features of its rivals, were fully described, and it was shown that though this engine was but 4½ tons in weight, and had a mere fraction of the power of the present locomotive, it contained the principles which are the essential ones of the modern engine, and marked the passage of the boundary line between experiment and success. The lecturer contrasted this primitive 10 mile an hour line with one now proposed between the very same towns, at the investigation of which, by the House of Commons, he was recently present. In this, the proposal is to run 10 minute electric trains, at no less a speed than 110 miles an hour. It was not till some years after 1830, the date of the opening of the Liverpool and Manchester railway, that the public began to realise thoroughly that it was more than an experiment, and amusing anecdotes were given showing the attitude more especially of, old people, towards the new method of locomotion. Attention was also drawn to the fact that its subsequent enormous development was not seriously believed in for a long time, as the absence of allusion to it in the literature of the early thirties showed. The various appliances which, since 1830, have brought the primitive contrivance of those days to the perfected one of to-day, were rapidly referred to,

such as stations, signals, points and crossings, brakes, electric telegraph, etc., also the arrangements for greater comfort in travelling, the enormous increase in mileage, as well as in power and speed, and finally in the recent application of electricity to railway traction. The lecture closed with a few interesting statistics, such as the present mileage of the world's railways, which is about 500,000 with an annual increase of from 2 to 3%, the cost amounting to about £7,000,000,000, and with nearly 4,000,000 people employed. The London railway stations alone dealt with 2,000,000 passengers daily, the maximum being 150,000 at Liverpool Street Station. The great size of a great modern railway station such as that at Frankfort, was referred to, its area being equal to that of a large portion of the busy part of Sydney. The largest locomotives of to-day were of 140 times the power specified for the Liverpool trial engines of 74 years ago. As an instance of the safety of the enormous traffic of the present day, it was mentioned that nearly 31,000,000 passengers were carried on the New South Wales railways in the last financial year, without a train accident causing loss of life to one of them. This was a great testimony to the carefulness and efficiency of the railway servant, a man who meeting possible death and always danger in his daily duties, especially in the crowded lines at home, is forgotten when medals, Victoria Crosses, and banquets are heaped on returning warriors who have probably incurred less risks. The lecture was illustrated by numerous lime light views.

ABSTRACT OF PROCEEDINGS, JULY 1, 1903.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, July 1st, 1903.

F. B. GUTHRIE, F.I.C., F.C.S., President, in the Chair.

Forty-six members and four visitors were present.

The minutes of the preceding meeting were read and confirmed.

Messrs. J. A. SCHOFIELD and C. J. McMASTER were appointed Scrutineers, and Mr. HENRY G. SMITH deputed to preside at the Ballot Box.

The following gentlemen were duly elected ordinary members of the Society:—

Bayly, Francis William, Royal Mint, Sydney.
Carslaw, Prof. H. S., M.A., D.Sc., University of Sydney.
Cooper, D. J., M.A., Superintendent of Technical Education.
McLaughlin, John, 70 Pitt Street.
Minell, William Percival, 163 Pitt Street.
Owen, Rev. E., The Vicarage, Hunter's Hill.
Rooke, Thomas, Assoc. M. Inst. C.E., Town Hall, Sydney.
Vonwiller, Oscar U., B.Sc., University of Sydney.
Walsh, Fred., "Walworth," Park Road.

The certificates of nine candidates were read for the third time, of two for the second time, and of three for the first time.

Twenty-eight volumes, 149 parts, 11 reports, 16 pamphlets, 1 geographical map, and 1 geological chart, total 206, received as donations since the last meeting were laid upon the table and acknowledged.

The President announced that the Third Science Lecture for the present Session would be delivered on the 23rd July

by F. LLOYD, B.A., LL.B., on "Ancient Italian Life." (Postponed.)

Also that the first Session of the Engineering Section would be held on July 20th, 22nd and 24th at 8 p.m., when eleven papers on the subject of "Water Conservation and Irrigation," including a lantern lecture on "The Murray," would be read and discussed. His Excellency the State Governor, Vice-Patron of the Society, had kindly consented to attend, and tickets of admission could be obtained from the Hon. Secretaries.

THE FOLLOWING PAPERS WERE READ:

1. "The Sand-drift problem in New South Wales," by J. H. MAIDEN, F.L.S.

The author stated that the question of sand-drifts is of national importance, and that it may be divided into the coastal problem, the sand dunes along the coast, and the western problem, dealing with the shifting sands in the arid western interior. It will be convenient to treat them separately.

I. *The Coastal Problem.*—The author showed what had been done in reclaiming sand-dunes in the special cases of (*a*) Newcastle, and (*b*) Bondi, near Sydney. The sand-drift problem is a forestry rather than an engineering question, and is so dealt with in countries outside Australia. Sand-dune reclamation consists of three stages:—1. Cutting off the further supply of sand from the ocean. 2. Fixing the sand by means of vegetation. 3. Maintenance of such vegetation. The author dealt with these points in detail, under (1) explaining the old French official method of forming the protective "dune littorale" and the modifications, in the direction of simplicity, which have been adopted in recent years. Under the head of (2) while agreeing that the Maritime Pine, used in the French Landes, is of great value even in New South Wales, he recommends the use of

the Norfolk Island Pine (*Araucaria excelsa*) as the staple tree for reafforestation of our coastal sand-dunes with a useful timber, and recommends one of the Tea-trees (*Leptospermum lævigatum*) as the "nurse" plant for establishing the young trees. Also he insisted on the element of time, as people sometimes appear to think that a crop of trees can be raised in pure sand in a period that experts know to be impossible. Under (3) he dealt with the important matter of protection against fire and of the adequate fencing of the young plantations. He then gave a brief list of plants recommended for this important work, dividing them into indigenous trees, shrubs, and grasses, and exotic trees, shrubs, and grasses respectively. He insisted on the necessity for utilizing the indigenous vegetation, which is specially suitable, because of a long period of adaptation, for this particular duty.

II. *The Western Problem.*—He attempted to define the area of the sand-drift country, and divided the western country into three classes. 1. The black earthy plains (the "black-soil plains") which crack when dry but which do not move. 2. Soil with more or less clay in it; this may blow away but it does not drift. 3. Drifting sands; these consist of clay, vegetable matter and sand. The lighter particles blow away in drought seasons, the remaining sands mostly red in colour but sometimes white are the driftiug sands of the west. He then touched upon the geological origin of the moving sand. The causes of drifting sands were the nattributed to:—1. droughts; 2. overstocking; 3. the rabbit pest; all of which had been more or less responsible for the removal of the sparse indigenous vegetation which had tended to knit the sand together. He dealt with each point in some detail and discussed the prevailing winds which cause the movement of the sand. He then proceeded to a discussion of remedial measures, pointing out, in the first place, that the principles of coastal sand-

dune reclamation (now so well understood) were broadly applicable in the case of the interior sand-dunes. He recommended the setting apart of experimental areas in different parts of the sand drift country, and that each depôt should be in charge of a trained man,—a first class gardener, of whom there are many in this State. Each gardener-in-charge would prepare areas of sand for planting, and while this was proceeding he would collect seeds of the local indigenous vegetation and would plant them on the areas, say 150 feet long and 50 feet broad, so prepared. He would also conserve the indigenous vegetation already existing as well as planting afresh. One small area having been treated, others could be established under the lee of the first one, and thus areas of indefinite extent could be fixed. The gardener-in-charge of a depôt could also establish an experimental nursery, and the wasteful method of trying to grow plants raised in the coast districts should be put a stop to as soon as possible. The trained man would be a focus of information in regard to planting questions for the benefit of the pastoralists and others, and his presence would be altogether desirable in the interests of western settlement.

The author only advocated the establishment of temporary or experimental depôts, but he felt sure that, if suitable men were appointed, their work would prove so valuable that there would be no difficulty in obtaining funds for extending the work. He recommended the Cypress Pines *(Callitris)* as the trees mainly to be used for the arrest of of the sand, and insisted on the paramount value of the indigenous vegetation for that purpose. Besides enumerating a few indigenous species he added a brief list of useful exotic species.

Remarks were made by Professor David and Mr. R. Helms. On the motion of Mr. C. A. Benbow, the discussion of this paper was postponed to the next General Monthly Meeting.

2. "Aluminium the chief inorganic element in a Proteaceous tree, and the occurrence of Aluminium Succinate in trees of this species," by HENRY G. SMITH, F.C.S., Assistant Curator, Technological Museum, Sydney.

In this paper the author announces the discovery of a flowering plant which uses the element aluminium in large quantities in its construction, and thus differs in this respect, from all other Phanerogams. This plant, *Orites excelsa*, R. Br., (N.O. Proteaceæ) is one of the "Silky Oaks" of Australia, and occurs plentifully in northern New South Wales and Queensland. It is a tall tree and reaches a diameter of three feet. A section of a tree from Queensland was exhibited which was three feet in diameter. In the centre of this tree was a large deposit of a basic aluminium succinate of the formula $Al_2(C_4H_4O_4)_3Al_2O_3$. The ash of the wood furthest from the deposit contained 79·61 per cent. of alumina, a considerably larger amount than had previously been found in any of the Cryptogams, in which alone aluminium was supposed to occur. This specimen was evidently an abnormal one in regard to the large amount of alumina, and the deposit of aluminium succinate is evidently nature's method of getting rid of an excess of aluminium. Three other samples of the trees of this species from northern New South Wales were investigated, and in the ash of all these large quantities of alumina were found, ranging in amount from 36 to 43 per cent. A large amount of the alumina in the ash was present as an aluminate of potash soluble in water, and as no carbonate of potash was detected it is supposed that the potassium aluminate was originally present in the tree as such. In the ash of the sample from Mullimbimby, cobalt was found, together with 3 per cent. of manganese, so that probably cobaltiferous manganese occurs in that locality. Free normal butyric acid was found in the succinate

deposit, this was separated and determined by its barium salt; no other volatile acid could be detected. It is evident that the succinic acid is derived from the butyric acid by natural oxidation, and it then probably forms the basic salt with the aluminium in solution. Investigation was made of the ash of *Grevillea robusta*, of *G. Hilliana*, and of *G. striata*, but no alumina could be detected in either, so that the statement previously made (this Journal 1895), that aluminium succinate occurred in the timber of *Grevillea robusta* was evidently made in error, and it is probable that the tree from which that deposit was obtained was *Orites excelsa*. When portions of the wood of the Queensland sample were ignited, it was possible to obtain the characteristic cobalt-blue colour for alumina when the ash was moistened with cobalt nitrate and ignited, the other salts being too small in amount to interfere with the reaction.

Remarks were made by Mr. R. T. Baker, Mr. Steele, Dr. R. Greig Smith, Prof. David, and the President. Mr. Smith, replied.

The paper on "The Economic effect of Sanitary Works," by J. HAYDON CARDEW, Assoc. M. Inst. C.E., had, owing to the lateness of the hour, to be postponed to the next General Monthly Meeting.

EXHIBITS.

Mr. C. A. Süssmilch exhibited gold and antimony ores from Hillgrove, including specimens of native antimony, cervantite, stibnite, kermesite, and bournonite.

The following is an abstract of the second Science Lecture of the present Session, delivered on the 25th June, by R. T. BAKER, F.L.S., Curator of the Technological Museum, on "The Australian Flora." The very high antiquity of this remarkable Flora was illustrated by slides and living specimens of the "Burrawang," *Macrozamia spiralis*,

Miq. the "Bunya-Bunya, *Araucaria Bidwilli*, "Native Honeysuckle" *Banksia spp.*, Eucalypts etc., which were exhibited and their history traced back to the Oolitic, Eocene and other respective periods of the earth's history. Incidently the Fauna was also laid under contribution to prove the geological age of this continent, reference being made to the Port Jackson Shark, *Cestracion Phillipi*, Ceratodus, Mollusca and Marsupials, the idea being to show that our fauna and flora instead of being as popularly supposed the newest on the world's surface are even "older than the hills." The long line of botanical investigators received special reference. The first of this class was the Buccaneer W. Dampier who visited the North West Coast in 1688 and whose botanical collections are now in the Sherardian Herbarium, Oxford University. Sir Joseph Banks was specially mentioned, reference being made to the debt of gratitude which Australia owes to this eminent man of science who was the real founder of the establishment of a British community on this continent, and who also contributed largely from his private fortune towards its scientific investigation. The botanical labours of Robert Brown, A. Cunningham, Baron von Mueller, Sir J. D. Hooker and others received well merited recognition. The systematic classification and peculiar characteristics of this remarkable flora was dealt upon at some length, whilst its affinities to and differences from existing floras were fully demonstrated. The latter part of the lecture was devoted to the valuable economics of this unique flora and was capitally illustrated with well prepared lantern slides and specimens, the genus Eucalyptus receiving very marked attention. Very effective and interesting exhibits of forest (primary and bye) products formed a special feature of the lecture, an object lesson in themselves.

ABSTRACT OF PROCEEDINGS, AUGUST 5, 1903.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, August 5th, 1903.

F. B. Guthrie, F.I.C., F.C.S., President, in the Chair.

Forty members and five visitors were present.

The minutes of the preceding meeting were read and confirmed.

Mr. F. W. Bayly enrolled his name and was introduced.

Messrs. G. R. Cowdery and T. H. Houghton were appointed Scrutineers, and Mr. S. H. Barraclough deputed to preside at the Ballot Box.

The following gentlemen were duly elected ordinary members of the Society:—

Bruck, L., 15 Castlereagh Street.

Jenkinson, Edward H., 15 Macquarie Place.

The certificates of two candidates were read for the third time, of three for the second time, and of four for the first time.

Twenty-seven volumes, 224 parts, 6 reports and 6 pamphlets, total 263, received as donations since the last meeting were laid upon the table and acknowledged.

The President announced that a Conversazione would be held in the Great Hall of the University, on Thursday, August 27th at 8·30 p.m.

He also referred to the death of Mr. F. Lloyd, B.A., LL.B., Curator of the Nicholson Museum, Sydney University, who was to have delivered the third Science Lecture this Session on "Ancient Italian Life."

The following letter was received from Lord Kelvin, acknowledging his election as an Honorary Member of the Society:—

15 Eaton Place, S.W. 29 June, 1903.

Dear Sir,—I have received your letter of the 21st May, and I desire through you to express my warmest thanks to the Royal Society of New South Wales for the honour they have kindly conferred on me in electing me to be an Honorary Member of the Society. With thanks to yourself for your letter,

I remain, yours faithfully,
KELVIN.

GEO. H. KNIBBS, Esq.

The discussion upon Mr. J. H. MAIDEN'S paper "The sand-drift problem in New South Wales," postponed from the previous meeting, was continued, the following gentlemen taking part—Messrs. C. A. Benbow, C. J. McMaster, W. A. Dixon, and R. Etheridge.

THE FOLLOWING PAPERS WERE READ:

1. "The Economic Effects of Sanitary Works," by J. HAYDON CARDEW, Assoc. M. Inst. C.E.

The author dealt with the economic effects and general benefits of sanitary works on large cities, instancing the works carried out in thirteen large cities of the world. The city of Sydney, he stated, had led the way in sanitary works in Australia, and, if viewed from the standpoint of sanitary results alone, would serve as an admirable object lesson to the rest of the Commonwealth. The author held that the elements of sanitary science should be taught in the public schools. The principal object of the paper was to give municipal and health authorities some basis to work upon in devising sanitary services and forecasting their economic effects. The death-rate of the cities aforesaid, which embraced Sydney, Melbourne, Brisbane, and Adelaide, was analysed and illustrated by large diagrams, going back to the very earliest records, and in the case of London the effects of the plague and its gradual elimination with the advance of sanitary knowledge, was very clearly and graphically illustrated. The history of the various commissions that were appointed to enquire into the health of

towns from the time of Henry III. to that of Queen Victoria was briefly sketched. The mode of assessment in money value of lives saved by sanitary works was explained on the lines laid down by the most eminent authorities, and it was clearly shewn that the expenditure on these works was fully justified from an economic standpoint, and that the savings effected in money value amounted to about a ten years' purchase of the various works. One notable economic effect due to sanitary works is the balancing of the losses in population due to the decrease of the birth-rate, which of late years has been of a serious character, and a diagram was exhibited showing this phase of the question for all the principal countries in the world and the principal towns in Australia. In addition to the diagrams already mentioned, the author exhibited diagrams showing the curves of population and expenditure on water supply and sewerage works for Sydney, Melbourne, and London, and a diagrammatic illustration containing all the information required for an exhaustive study of the question.

A discussion ensued in which the following gentlemen took part:—Dr. R. Greig Smith, Mr. W. A. Dixon, Dr. F. H. Quaife, Mr. W. E. Cook, and the Chairman. Mr. Cardew replied.

2. "On the protection of Iron and other metal-work," by WILLIAM M. HAMLET, F.I.C., F.C.S., Government Analyst.

The author pointed out that the stability and permanence of the materials used in building construction depended on the application of a knowledge of chemistry and physics, and that the engineer, architect, and builder, must keep in touch with this knowledge in order to make the best use of the nature and possibilities of their materials; and just as the chemist seeks a knowledge of the structure and disintegration of matter, so also will he know of the best means to adopt for the protection of materials against the wear

and tear of atmospheric and other influences. Any given structure, whether it be a ship, an engine, a house, or a bridge, will, if left to itself, become weathered, perish, and decay, unless protected. The many hosts to be thus reckoned with are:—Chemical and electrical influences, mechanical and meteoric changes, erosion by sand, wind, and rain, factory-chimney emanations, all more or less accelerated by contraction and expansion, together with biological influences and animal depredations. It is found that by examining the structure of a metal, much useful information may be obtained as to its powers of resistance under given circumstances. A section of a metal for instance is highly polished and then etched by an acid, an alkali, or a peroxide, either applied directly or by electrolytic methods. From the visible grain, texture, or structure, as seen under the microscope, good and bad materials may be differentiated one from another. This method of examination and testing materials has come rapidly into use during recent years, and is particularly useful in the case of iron, steel, bronze, brass, Muntz, and other yellow metals. The rusting of iron and steel is dealt with, the author referring to experiments made from time to time during the last fifteen years, and the immediate cause of the publication of this paper at the present time was owing to a paper published in a recent number of the Journal of the Chemical Society by Dunstan, followed by a similar one by Moody on the rusting of iron. The former observer lays stress on the action of hydrogen peroxide, while the latter accounts for rust by the action of carbonic acid, which action he compares to the action of any mineral acid on iron with the consequent liberation of hydrogen. Petit, in 1896, showed that the mere presence of carbonic acid gave rise to corrosion and formation of ferrous carbonate, which is one of the antecedent products in the formation of rust. The author was engaged in a work of investigating the causes of the

rapid corrosion or rusting away of the iron casing at one of the Australian artesian bores, where abundance of carbonic acid gas was evolved at the rather high temperature of 100° Fahr., the water also contained alkaline carbonates and bicarbonates with sodium chlorides, silica, etc., amounting to between thirty and forty grains of total solid matter to the gallon. This is an admittedly difficult case to deal with, and probably a specially hard and resistant alloy will be required to stand the prolonged and severe action of the water in question. The protection of ironwork under usual conditions is best effected by the use of a paint or an enamel having a co-efficient of expansion equal or nearly equal to that of the iron itself, so that cracking or bursting of the skin of paint shall be prevented which would otherwise lead to exposure of the bare iron to outside influences. Dr. Angus-Smith's composition, the Bower-Barff process, red lead, iron oxide, asphalte, and graphitic paints were each considered, the author holding a high opinion of simple pure red lead and genuine linseed oil as an excellent covering for most purposes. Galvanised iron, lead, bronze, Muntz metal, and copper were each referred to, especially to the action of the air of towns and manufacturing districts.

The following papers were taken as read:—

3. "On the elastic radial deformations in the rims and arms of flywheels, and their measurement by an optical method," by A. BOYD, B.Sc., B.E., Stud. Inst. C E. [Communicated by Prof. WARREN, M. Inst. C.E., Wh. Sc.]

The author points out that hitherto the only experimental work that has been done on this subject has been to burst flywheels and measure their bursting speed, attempts being made to deduce the cause of weakness in any wheel from its mode of fracture. As the wheels were almost absolutely shattered in each case, the first point of fracture was difficult to determine. In this paper, actual measurements

of the deflections of the rims during rotation are given, so that the shape of the rim at any speed within the elastic limit of the material can be seen. A set of diagrams is given for each of six flywheels, shewing the deflections of points round the rims at rising speeds and the deformations of the rims at any particular speed. The flywheels tested were of different design as follows:—1 Three armed wheel straight arms; 2 Four armed wheel straight arms; 3 Four armed wheel curved arms; 4 Six armed wheel straight arms; 5 Four armed wheel straight arms, jointed midway between the arms; 6 Four armed wheel straight arms, jointed along the arms. The curves for the curved armed wheel show a large inflection between the arms, the maximum deflection being close to the arms. The tests on the last two wheels show very clearly the great advantage of having the joint along the arms, the effect of the joint in the last wheel being in fact almost negligible. The deflections obtained for the straight armed wheels without joints are compared with the deflections as calculated by Professsor Lanza's theory, and a method of finding the equations to the curves of the rims is illustrated. A clear description of the measuring apparatus is given by which a deflection of $\frac{1}{12000}$th part of an inch can be measured while a wheel is rotating. The speeds are accurately measured by means of a chronograph, the revolutions of the wheel being recorded on smoked paper together with the vibrations of a tuning fork making 100 vibrations per second. The physical properties of the material of the wheels were determined, tensile tests and transverse tests being made on specimens cast with the wheels. The extensions in the tensile tests were measured by the Martens' mirror apparatus and the modulus of elasticity obtained. The deflections in the transverse tests were measured by means of a microscope, the specimens being tested resting on knife

edges, and also encastré, the modulus of elasticity being determined for each case.

4. "The Aboriginal Fisheries at Brewarrina," by R. H. MATHEWS, L.S.

The author gave an exhaustive description of the construction, and the method of using these interesting examples of native workmanship; a plan was referred to showing the position and shape of the fishing traps or pens in the bed of the river Darling. Brief reference was made to the wearing away of the rocky bar across the river, thus forming numberless boulders of different sizes, which were used by the aboriginal builders in constructing the traps.

On account of the lateness of the hour, the following were postponed to the next meeting:—

5. "The Geology of the Mittagong District," by T. GRIFFITH TAYLOR and D. MAWSON, B.E. [Communicated by Prof. T. W. E. DAVID, B.A., F.R.S.]

6. "The separation of Iron from Nickel and Cobalt by Lead Oxide (Field's method)," by T. H. LABY. [Communicated by Prof. LIVERSIDGE, M.A., LL.D., F.R.S.]

6. "Pot experiments to determine the limits of endurance of different Farm-crops for certain injurious substances, Part II. Maize," by F. B. GUTHRIE, F.I.C., F.C.S., and R. HELMS.

CONVERSAZIONE.

A Conversazione was held in the Great Hall of the University, on Thursday, 27th August, at 8·30 p.m., under the management of the Officers and Council of the Royal Society. The Hall and approaches were tastefully decorated with palms, ferns, and rare pot plants.

The University grounds were illuminated with electric light and fairy lamps, thus enabling the guests to visit the

various laboratories, all of which were thrown open, likewise the Medical School.

There were upwards of 500 guests, His Excellency the Governor-General and Lady TENNYSON, in consequence of their departure for Melbourne, being unable to attend. His Excellency the State Governor and Lady RAWSON, were present, also Brigadier-General and Mrs. FINN, together with the District Head-Quarters' Staff, Officers of the ships of War in harbour, including the Captain and Officers of H.I.G.M.S. "*Condor*," His Grace Archbishop KELLY, and the heads of various religious denominations, Members of the University Senate, many of the Consuls-General and Vice-Consuls, The Honble. J. PERRY, Minister of Public Instruction and others.

EXHIBITS.

Mr. C. O. BURGE—Old Engravings and rare books.

Mr. R. T. BAKER—Exhibits from Technological Museum.

Mr. H. E. BARFF—Book of Photographs of the University of Tokio, Japan.

Mr. HENRY DEANE—Models of the New Central Railway Station:—Clock Tower, Smaller Tower, Arrival Bridge, General View.

His Honour JUDGE DOCKER—Stereoscope and set of stereographs of Tasmanian Scenery.

Mr. W. PERCY FAITHFULL—New form of Microscope by Zeiss of Berlin, magnifying up to 100.

GEOLOGICAL SURVEY, N. S. WALES—Framed photographs of N. S. Wales Geology. Meteorite and casts from Gilgoin Station N. S. Wales. Miscellaneous Minerals.

Mr. W. M. HAMLET—Microscope showing metallic structure by etching methods now used in metalloscopy, microscopes.

Mr. H. L. JONES—Clark Automatic Telephone Switchboard. Model of modern bogey frame with wheels, used on heavy railway tracks in the United States.

Mr. J. PERCY JOSEPHSON—Book of Engravings of Ancient Rome and Italy.

Mr. J. H. MAIDEN—Copies of plans of the Botanic Gardens and Government Domains from 1807 to 1880.

Mr. A. B. PATERSON—Curios, etc. Pen and Ink sketch of Sir Alfred Stephen by the late Phil May.

Dr. F. H. QUAIFE—A Projecting Microscope.

Dr. WALTER SPENCER—Historical Miniature portraits on ivory. Albums (2) Costumes and Scenes of the East. Old Books and Prints, English antiques, Oriental curios and coins.

Mr. P. C. TREBECK—Photographs (2) Niagara Falls.

UNIVERSITY OF SYDNEY—Rare Books.

Mr. ERNEST W. WARREN—Physical apparatus:—Vacuum Tubes, X Rays, High Frequency apparatus, Induction coils, etc.

Senator J. T. WALKER—Engraving by Martin Hemskirk, A.D. 1549. Memento of King Edward the Confessor and Westminster Abbey A.D. 1066.

ABSTRACT OF PROCEEDINGS, SEPTEMBER 2, 1903.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, September 2nd, 1903.

F. B. GUTHRIE, F.I.C., F.C.S., President in the Chair.

Thirty-three members and one visitor were present.

The minutes of the preceding meeting were read and confirmed.

Dr. WALTER SPENCER and Dr. R. GREIG SMITH were appointed Scrutineers, and Dr. QUAIFE deputed to preside at the Ballot Box.

The following gentlemen were duly elected ordinary members of the Society:—

McDonald, Robert, Double Bay.
Meggitt, Loxley, Alexandria.
Scott, William B., Homebush.

The certificates of three candidates were read for the third time, of four for the second time, and of one for the first time.

Twenty volumes, 105 parts, 9 reports, and 9 pamphlets, total 143 received as donations since the last meeting were laid upon the table and acknowledged.

The Chairman announced the following alterations in the dates fixed for lectures; the first of the Clarke Memorial Lectures by Prof. T. W. E. DAVID, would be delivered on the 24th September instead of the 17th. The Science Lecture on "The physical characteristics of the Moon," by Professor WOODHOUSE would not be given, and the lecture on "Some features of Modern Technology" by Mr. G. H. KNIBBS, (arranged for September 24th) would be delivered on November 26th.

The following letter was received from Lord LISTER, acknowledging his election as an Honorary Member:—

12 Park Crescent, Portland Place,
8th July, 1908.

My Dear Sir,—Allow me to express through you my cordial thanks to the Royal Society of New South Wales for the great honour they have done me in electing me an Honorary Member of their Body.

Believe me,
Very sincerely yours,
LISTER.

J. H. MAIDEN, Esq.

THE FOLLOWING PAPERS WERE READ.

1. "The separation of Iron from Nickel and Cobalt by Lead Oxide (Field's method)," by T. H. LABY. [Communicated by Prof. LIVERSIDGE, M.A., LL.D., F.R.S.]

The accurate separation of iron from nickel and cobalt is peculiarly difficult.

Review of methods.—Ammonium hydrate and chloride. The ferric hydrate precipitate carries down so much of the nickel and cobalt present as to require three reprecipitations.

Ammonium carbonate.—This much recommended separation is long and tedious.

Basic acetate.—Using a small quantity of acetate to precipitate the iron, 99% of the nickel or cobalt can be recovered with one precipitation. But it is not readily combined with the electrolytic determination of the nickel, and sometimes the precipitate of iron is very difficult to filter. Several *electrolytic separations* have been devised. But conflicting statements have been made as to their accuracy. Gooch and Medway, using a rotating cathode, have accurately deposited nickel in half-an-hour.

Rothe's extraction of ferric chloride by ether is being considerably used. The concentration of the reagents added is of more than usual importance.

Experimental.—An inquiry into the accuracy of Field's method was made, as it had distinct advantages over methods commonly in use, viz., a *single* precipitation of the iron, and the absence, after the removal of added lead, of all reagents such as sodium or ammonium salts. Combined with the electrolytic determination of nickel or cobalt, the method becomes more rapid than, say, a double precipitation of the iron by the basic acetate process, and the precipitation of the nickel and cobalt as sulphides. Standard solutions of carefully purified iron, nickel, and cobalt nitrates, were prepared. With these solutions twenty-two analyses were made, showing a recovery of over 99% of nickel and cobalt, which is a somewhat better recovery than can be made by a single basic acetate separation.

Some remarks were made by the Chairman.

2. "Pot experiments to determine the limits of endurance of different Farm-crops for certain injurious substances, Part II. Maize," by F. B. GUTHRIE, F.I.C., F.C.S., and R. HELMS.

The authors communicated the results of experiments having for their object to determine the tolerance of maize for sodium chloride, sodium carbonate, ammonium sulphocyanide, sodium chlorate and arsenious acid. These were conducted in a manner precisely similar to the series of experiments with wheat, published in the Royal Society's Proceedings, Vol. XXXVI., pp. 191 *et seq.*, the results obtained being summarized in the following table:—

Effect upon germination and subsequent growth of Maize of different percentages of injurious substances in the soil.

	Germination affected.	Germination prevented.	Growth affected.	Growth prevented.
$NaCl$	·20	·50	·10	·25
Na_2CO_3	·20	·50	·10	·25
NH_4CNS	·005	above ·02	·001	above ·02
$NaClO_3$	·004	above ·006	·001	·004
As_2O_3	·50	above ·80	·05	·60

Remarks were made by the following gentlemen:— W. M. Hamlet, J. H. Maiden, Prof. Liversidge, Dr. R. Greig Smith, J. U. C. Colyer, Lewis Whitfeld. Mr. Guthrie replied.

3. "Bibliography of Australian Lichens," by E. CHEEL. [Communicated by J. H. MAIDEN, F.L.S.]

Remarks were made by Mr. Maiden in explanation of the Bibliography.

4. "On the Narraburra Meteorite," by Prof. LIVERSIDGE, M.A., LL.D., F.R.S.

This metallic meteorite, weighing over 70 lbs., was discovered in 1855 on the Yeo Yeo Creek, twelve miles east of Temora, N.S. Wales, and was exhibited to the Society by Mr. H. C. Russell, C.M.G., Government Astronomer, in 1900. A general account of the characteristics of this meteorite was given, and a series of seven slices which had been prepared so as to show the internal structure of the meteorite from the exterior to the centre. The meteorite was very difficult to cut in places. The crystalline structure is remarkable, and a series of photographs was shown to illustrate the paper.

Some remarks were made by Professor Hussey (of the Lick Observatory, California), and the Chairman.

The paper on "The Geology of the Mittagong District," by T. GRIFFITH TAYLOR and D. MAWSON, B.E. [Communicated by Prof. T. W. E. DAVID, B.A., F.R.S.] was postponed.

EXHIBITS.

1. Crystallised Eucalyptol. Mr. HENRY G. SMITH, F.C.S., exhibited on behalf of the Australian Eucalyptus Oil Company about four pounds of crystallised eucalyptol, which had been frozen out from the oil of *Eucalyptus Smithii*, R.T.B., by the Metropolitan Ice Company, Harris Street, in a special apparatus. The use of pure eucalyptol, instead of the oil,

is now common, and the product obtained by freezing is superior to that obtained by the use of either phosphoric acid or of hydrochloric acid, because the eucalyptol is free from contamination, besides being prepared more cheaply.

2. A copy of Hooke's "Micrographia," date 1665, was exhibited by Mr. C. O. Burge, M. Inst. C.E.

ABSTRACT OF PROCEEDINGS, OCTOBER 7, 1903.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, October 7th, 1903.

F. B. GUTHRIE, F.I.C., F.C.S., President, in the Chair.

Twenty-seven members were present.

The minutes of the preceding meeting were read and confirmed.

Messrs. P. N. TREBECK and STANLEY JEVONS were appointed Scrutineers, and Dr. WALTER SPENCER deputed to preside at the Ballot Box.

The following gentlemen were duly elected ordinary members of the Society:—

Arnott, Arthur James, A.M.I.C.E., M.I.M.E., M.I.E.E., 83 Pitt-street.

Forde, James, B.A., B.Sc., Technical College.

Irvine, R. F., M.A., Musgrave-street, Mosman.

Webb, Arthur C. F., Vickery's Chambers, Pitt-street.

The certificates of four candidates were read for the third time, of one for the second time, and of two for the first time.

Twenty-five volumes, 204 parts, 21 reports and 9 pamphlets, total 259, received as donations since the last meeting were laid upon the table and acknowledged.

The President announced that the Third Science Lecture 1903, on "Water," would be delivered by Prof. LIVERSIDGE, M.A., LL.D., F.R.S., in the Chemistry Lecture Theatre at the University, on Thursday, October 22nd, at 8 p.m.

That the next meeting of the Australasian Association for the Advancement of Science would probably be held about January 6th, 1904, at Dunedin, N.Z. He mentioned that the Union Steamship Company would allow a discount of 20% off the usual fares to all members of the Association, and that the New Zealand Government had very generously offered free passes to members over all the railway lines for a month. Any information in connection with the meeting could be obtained on application to the Permanent Honorary Secretary (Professor Liversidge) at the Sydney University.

THE FOLLOWING PAPERS WERE READ:

1. "The Geology of the Mittagong District," by T. GRIFFITH TAYLOR and D. MAWSON, B.E. [Communicated and read by Prof. T. W. EDGEWORTH DAVID, B.A., F.G.S., F.R.S.]

The authors show in this paper that the eruptive rocks of this district are all of Post-Triassic age. They are divisible into two series (1) an alkali-felspar series, and (2) a basic series. The former is typically represented by the so-called trachyte or syenite of the Gib-Rock, (allied to the rocks bostonite or nordmarkite, 'monzonose' of the new American petrological classification) and of Mount Jellore. The latter rock contains an interesting blue amphibole allied to arfvedsonite, but having special physical properties notably very strong absorption, which distinguish it from that mineral. The latter series (basic series) comprises in

addition to dolerites and basalts a very interesting group of basic to ultrabasic rocks, classed by the authors as essexites and pikrites. The last contain rather less than 39% of SiO_2. The iron ore deposits of Mittagong, of late Cainozoic age, are considered to have had their origin in chalybeate springs, which have derived their bicarbonate of iron, by a process of leaching, from the underlying alkali felspar eruptive rocks. Chemical analyses have been made by the authors of six of the eruptive rocks, as well as of the blue amphibole, and full petrological descriptions are given of all the type rocks of eruptive origin found in the district.

Remarks were made by Mr. Stanley Jevons, B.A. *Cantab.*, B.Sc. *Lond.*, and the authors.

2. "Notes on some Native Dialects of Victoria," by R. H. MATHEWS, L.S.

Mr. R. H. Mathews, L.S., of Parramatta, read a paper entitled "Notes on some Native Dialects of Victoria," embracing the central and western districts. If this paper be read in connection with the author's former articles on "The Aboriginal Languages of Victoria," "The Yotayota Language," and "The Bureba Language," it will be found that the grammatical structure of the speech of the Victorian Aborigines has been recorded with tolerable fulness.

EXHIBITS.

1. Specimens of chrysocolla, a hydrous silicate of copper, showing crystals, pseudomorphous after azurite, from Chillagoe, Queensland, exhibited by Mr. C. A. Süssmilch.

2. "Obsidian Bombs" forwarded by Mr. P. Le Mesurier of Eucla, Western Australia, were exhibited by Mr. Henry Deane, M.A., M. Inst. C.E.

Remarks were made by Professor David.

ABSTRACT OF PROCEEDINGS, NOVEMBER 4, 1903.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, November 4th, 1903.

F. B. GUTHRIE, F.I.C., F.C.S., President, in the Chair.

Eighteen members were present.

The minutes of the preceding meeting were read and confirmed.

Messrs. G. H. HALLIGAN and T. F. FURBER were appointed Scrutineers, and Mr. C. O. BURGE deputed to preside at the Ballot Box.

A quorum not being present, the ballot could not be held.

The certificate of one candidate was read for the third time, of two for the second time, and of three for the first time.

Eighty-seven volumes, 111 parts, 6 reports and 3 pamphlets, total 207, received as donations since the last meeting were laid upon the table and acknowledged, including 79 volumes presented by the Bureau Central Météorologique, Paris, through the kind offices of Mr. G. H. KNIBBS when on the Continent.

THE FOLLOWING PAPERS WERE READ.

1 "On some further observations on the Life-history of *Filaria immitis*, Leidy," by THOS. L. BANCROFT, M.B., Edin.

In this paper Dr. Bancroft, (who has at various times during the past fifteen years worked at filarial diseases of the human subject, the dog, and birds), has detailed the results of final work on this subject. He has succeeded, through the agency of mosquitoes, in transmitting *Filaria immitis* from an infected to several healthy dogs, and has also observed the manner in which the young filaria leaves

the mosquito's proboscis. These observations are most valuable, for by analogy they are referable also to *Filaria Bancrofti*, a parasite, which causes untold misery and great suffering to the human race throughout the world.

Some remarks were made by Dr. Walter Spencer.

2. Mr. J. H. MAIDEN initiated a discussion on "Some Lessons of the Drought."

He divided his remarks into three heads, all interdependent, viz.:—(1) The facts. (2) What are we to do? (3) The insurance idea.

Under (1) he brought under notice the monetary cost and remarked on—

(*a*) The cash outlay for fodder in a drought.

(*b*) The cutting up of the roads by fodder-waggons.

(*c*) The suffering of draught animals, of cattle and of sheep.

(*d*) Destruction of sheep by dingoes and other animals made desperate by starvation.

(*e*) Financial worries and even bankruptcy, and attendant suffering.

Then he dealt with certain items under the comprehensive heading of "Pests"—

(*a*) Weeds.[1] These have made great headway during the present favourable spring, but it must be remembered that their presence, in many cases, is directly traceable to the drought. A number of weeds have been shown to be new

[1] Mr. Maiden exhibited four bad weeds, not hitherto recorded for the State, which had come under his notice during the previous fortnight, viz.:—(1) *Amsinckia intermedia*, Fisch and Meyer, a yellow-flowered member of the Forget-me-not family, from Blayney. It is also a pest in California. (2) *Adonis autumnalis*, Linn., the Autumn Pheasant's Eye or Red Chamomile, a pretty plant belonging to the Buttercup family. It is a European plant, and comes from the Berrigal district. (3) *Lactuca scariola*, Linn., "Prickly Lettuce," from Barraba, a weed difficult to cope with because of its feathery seeds, and which he had already received from Aberdeen and Woollongbar in 1899. (4) *Sisymbrium orientale*, Linn., a weed belonging to the Mustard family and native of South Europe. This also hails from Barraba.

for the State, while others have made their appearance in districts widely separated from those which they were previously found.[1] In many cases their presence has been directly traced to imported fodder.

(*b*) Prickly Pear (*Opuntia*), a succulent pestilent weed, which has been tolerated during the drought because it has been used to some extent as a famine food. The nearly spineless forms may prove to be of use, but the common spiny species are a pest of the worst description.

(*c*) Mistletoe (*Loranthus*), which is increasing largely and killing useful trees, debilitated by the drought, and other causes.

(*d*) Rust in cereal crops is now appearing.

(*e*) Insects will probably give much trouble; they are getting aggressive now, also slugs and snails. They will directly reduce the crops and herbage that would otherwise be reaped after the drought.

(*f*) Bush-fires. We had serious fires of trees and shrubs during the drought. We must now prepare against grass fires.

(2) What are we to do?

(*a*) Study the periodicity of droughts and of good and bad seasons. What can meteorologists tell us?

(*b*) Study the statistics of production, of crops, stock, etc.

(*c*) Educate public opinion in regard to Mr. McMaster's idea of light railways for the West for the conveyance of threatened stock.

(*d*) Study the physical and chemical properties of our soils. The U.S. Department of Agriculture is doing much in this

[1] An instance of this is the Cape Weed, *Cryptostemma calendulacea*, R.Br. a Dandelion-looking plant, which has been sent this season from numerous New England localities as a stranger.

direction. What are we doing? Do not export the bones of pasture animals if it can be avoided.

(*e*) Cultivate and conserve drought-resistant fodder-plants.

(*f*) Conserve the natural fodder. It can be made into ensilage, or, better still it should be cut for hay wherever possible. Dry hay carefully stacked, not allowed direct contact with the ground and roofed over, will keep for an indefinite period. Some Queensland lucerne hay 23 years old, was sold during the last drought.

(*g*) Conserve the water,—in other words irrigate. We can grow anything with water and nothing without it, so that the conservation of fodder and of water are inseparably associated. Allusion was made to the recent successful conference on Irrigation carried on by the Engineering Section of our Society.

(3) The Insurance idea.

Having obtained knowledge in regard to the periodicity and intensity of our droughts and good seasons, and statistical information in regard to the fodder markets in and out of Australia, and other knowledge indicated, could we not follow the example of antiquity by making provision for the future,—by doing something to balance the lean years against the fat ones? Mr. Maiden pointed out that insurance offices have made elaborate tables as regards the incidence of all kinds of risks. *Inter alia*, he sketched a rough plan of a self-imposed annual tax of say (for the sake of argument) 5% of the net profits in any one year. The smaller the profit the smaller would, according to that arrangement, be the amount of fodder accumulated to the credit of the famine fodder fund. At last one would arrive at a time when profits would tend to the vanishing point; the famine would have approached, and it would be time to draw upon the famine fund. In districts in which,

although the seasons might be good, it might be physically impossible to harvest feed, then the voluntary famine tax would be expended in the purchase, during the same season, of fodder from districts in which it was available. The central idea is the same, self-imposed taxation to provide a reserve fund of fodder at the cheapest market rates to be held until necessity compels its use.

A very interesting discussion took place, in which the following gentlemen took part:—Mr. W. A. Dixon, Mr. P. N. Trebeck, Dr. Walter Spencer, Dr. F. H. Quaife, Mr. O. O. Burge, and Mr. H. V. Jackson (by invitation of the President). The President, in closing the discussion, owing to the lateness of the hour, expressed the opinion that the subject could be profitably continued on some future occasion.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, December 2nd, 1903.

F. B. Guthrie, F.I.C., F.C.S., President, in the Chair.

Twenty-nine members and one visitor were present.

The minutes of the preceding meeting were read and confirmed.

Messrs. G. H. Halligan and R. T. Baker were appointed Scrutineers, and Mr. Henry G. Smith deputed to preside at the Ballot Box.

The following gentlemen were duly elected ordinary members of the Society, viz:—

Old, Richard; North Sydney.

Kennedy, Thomas, Assoc. M. Inst. C.E., L.S.; Public Works Department.

Stoddart, Rev. A. G.; Manly.

The certificates of two candidates were read for the third time, and of three for the second time.

Twenty-nine volumes, 177 parts, 30 reports, 7 pamphlets, and one geological map, total 244, received as donations since the last meeting were laid upon the table and acknowledged.

The President announced that the Council had unanimously awarded the Clarke Memorial Medal to Mr. A. W. Howitt, F.G.S., of Melbourne.

THE FOLLOWING PAPERS WERE READ:

1. "A comparison of the Periods of the Electrical Vibrations associated with Simple Circuits," by J. A. Pollock, Professor of Physics in the University of Sydney, with an appendix by J. C. Close, Deas-Thomson Scholar in Physics.

In the research the periods of the electrical vibrations connected with narrow rectangular closed circuits have been compared with those of the oscillations associated with straight wires, with open and closed circles and with closed ellipses. Definite numerical results have been obtained for circuits varying in length from 3 to 9 metres. In the appendix experiments are described which shew the effect of separating the ends of a circular resonator from each other, on the period of vibration induct or circuit, a point which has not previously been considered.

Some remarks were made by Mr. G. H. Knibbs.

2. "A contribution to the study of the Dielectric Constant of Water at Low Temperatures," by O. U. Vonwiller, B.Sc.

The object of the experiments was to ascertain whether the dielectric constant of water had a maximum value at 4° C. or not. Electrical oscillations, with a frequency of 25 millions, were set up along two parallel wires divided by metal bridges into a primary and secondary circuit. A condenser placed across the wires on the secondary being equivalent to a change in length depending on the capacity, any variation in capacity results in a change in the resonance between the circuits, which is indicated by a Rutherford Detector. First an air condenser was used, readings being taken as its capacity was given different known values, and then a condenser having water as its dielectric, readings being taken as the temperature rose from 0° C. By comparing the readings obtained with the two condensers, the variation of capacity of the water condenser was estimated. The capacity invariably decreased as the temperature rose, there being no indication whatever of a critical value at 4° C.

Remarks were made by Professor Pollock, Mr. G. H. Knibbs, and the President.

EXHIBITS.

1. Model of a new Pressure Anemometer, by HENRY A. HUNT, F. R. Met. Soc.

2. Crookes' Spinthariscope (showing the scintillations of Radium), exhibited by Mr. G. H. KNIBBS, [kindly lent by Dr. L. HERSCHEL HARRIS.] Mr. KNIBBS gave a brief account of the characteristics of the radio-active elements and the significance of the phenomena to theoretical physics.

The following donations were laid upon the table and acknowledged :—

TRANSACTIONS, JOURNALS, REPORTS, &c.

(The Names of the Donors are in *Italics*.)

AACHEN—Meteorologische Observatorium Aachen. Auf der Industrie und Gewerbe-Ausstellung Düsseldorf 1902. Deutsches Meteorologisches Jahrbuch für 1901. *The Director*

ABERDEEN—University. Aberdeen University Studies, Nos. 5, 6, 7, 1902, *The University*

ACIREALE—R. Accademia di Scienze, Lettere ed Arti degli Zelanti. Atti e Rendiconti Memorie della Classe di Scienze, Nuova Serie, Vol. VIII., 1896-7; Vol. IX., 1897-8; Vol. X., 1899-0. Rendiconti e Memorie, Serie 3, Vol. I., 1901-2. Ricordi sul primo centenario della nascita di Lionardo Vigo, 1901. *The Academy*

ADELAIDE—Geological Survey of South Australia. Contributions (Nos. 12 and 13) to the Palæontology of South Australia by R. Etheridge, Junr, 1902. Report of the Government Geologist on the Phosphate Discovery, Hundred of Bright, S.A., 1903; Ditto, ditto, Hundred of Clinton, Yorke's Peninsula, 1902. Report on the White Range Gold Mines, Arltunga Goldfield, by H. V. L. Brown, 1902. Report on the Gold Discoveries near Winnecke's Depôt and Mines on the Arltunga Goldfields, Macdonnell Ranges by H. Y. L. Brown, F.G.S., 1903. *The Survey*

Observatory. Meteorological Observations during the year 1899. *The Observatory*

Public Library, Museum, and Art Gallery of South Australia. Report of the Board of Governors for 1901-2. *The Director*

Royal Geographical Society of Australasia. Proceedings of the South Australian Branch, Vol. V., Session 1901-2. *The Society*

Royal Society of South Australia. Memoirs, Vol, II., Part i., 1902. Transactions, Vol. XXVI., Part ii., 1902; Vol. XXVII., Part i., 1903. ,,

AGRAM—Société Archéologique Croate. Jahrbuch des Meteorologischen Observatoriums in Agram (Zagreb) für das Jahr 1901, Jahrg. I. Viesnik, N S., Svenska VI., 1902. ,,

AMSTERDAM—Akadémie Royale des Sciences. Jaarboek, 1901. Proceedings of the Section of Sciences, Vol. IV, 1902. Verslag van de Gewone Vergaderingen der Wis-en Natuurkundige Afdeeling van 25 Mei 1901 tot 19 April 1902, Deel X. Verhandelingen, Eerste Sectie, Deel VIII., Nos. 1, 2, 1901-2; Tweede Sectie, Deel VIII., Nos. 1-6, 1901-2; Tweede Sectie, Deel IX., Nos. 1-3, 1902. Paedologisch Jaarboek onder redactie van Prof. Dr. M. C. Schuyten, Jaargang 3 and 4, 1902-3. *The Academy*

ANNAPOLIS, Md.—U.S. Naval Institute. Proceedings, Vol. XXVIII., No. 4, 1902; Vol. XXIX., Nos. 1-3, 1903. General Index Vols. I.-XXVII. inclusive. *The Institute*

AUCKLAND—Auckland Institute and Museum. Annual Report for 1902-3. ,,

BALTIMORE—Johns Hopkins University. American Journal of Mathematics, Vol. XXIV., Nos. 2-4. 1902; Vol. XXV., No. 1, 1903. American Journal of Philology, Vol. XXII., No. 4, 1901; Vol. XXIII., Nos. 1-4, 1902. Historical and Political Science, Vol. XX., Nos. 2-12, and extra No. 1902. *The University*

Maryland Geological Survey. Cecil County and Maps; Garrett County and Maps, 1902. *The Survey*

BANGALORE—Mysore Geological Department. Report of the Chief Inspector of Mines for the year 1901. *The Department*

BATAVIA—Koninklijke Natuurkundige Vereeniging in Nederl-Indië. Natuurkundig Tijdschrift voor Nederlandsch-Indië, Deel LXII., 1903. *The Society*

BERGEN—Bergen Museum. Aarbog, Hefte 2, 1901; Hefte 1, 1902. Aarsberetning for 1901. An account of the Crustacea of Norway, Vol. IV., *Copepoda calanoida*, Parts vii. - xiv. 1902-3. *The Museum*

BERKELEY—University of California. Annual Report of the Secretary to the Board of Regents for the year ending June 30, 1901. Officers and Students, September 1902. College of Agriculture—Agricultural Experiment Station:—Bulletin Nos. 140 and Supplement, 141, 142, 144 - 148, 1902-3; Report of Work for the years 1898 - 1901, Parts i. and ii. University of California Bulletins, New Ser., Vol. IV., Nos. 1, 2, 3, Vol. V., No. 1; Ditto, Publications—Botany, Vol. I., pp. 1 - 418, 1902-3; Physiology Vol. I., Nos. 1, 2, 1903; Geology, Dept. Bulletin Vol. III., Nos. 1 - 12, 1902-3; Library Bulletin, No. 1, Third enlarged edition, 1902; University Chronicle, Vol. V. and Supplement 1902, Vol. VI., No. 1, 1903. *The University*

BERLIN—Gesellschaft für Erdkunde zu Berlin. Zeitschrift, Nos. 7 - 10, 1902; Nos. 1 - 3, 1903. *The Society*

Königlich preussische Akademie der Wissenschaften zu Berlin. Sitzungsberichte, Nos. 41 - 53, 1902; Nos. 1 - 40, 1903. *The Academy*

Königlich preussische Geodätisches Institutes. Veröffentlichung, Neue Folge Nos. 9 - 13, 1902-3. *The Institute*

Königlich preussische Meteorologische Instituts. Bericht über die Tatigkeit im Jahre 1902. Deutsches Meteorologisches Jahrbuch für 1902, Heft 1, Preussen und benachbarte Staaten. Ergebnisse der Beobachtungen an dem Stationen II. und III., Ordnung im Jahre 1896, Heft I. im Jahre 1898, Heft III. Ergebnisse der Gewitter-Beobachtungen in den Jahren 1898, 1899 und 1900. Ergebnisse der Niederschlags-Beobachtungen in den Jahren 1899 und 1900. Regenkarte der Provinzen Schleswig-Holstein und Hannover, etc. 1902. Regenkarte der Provinz Westfalen etc. 1903. Regenkarte der Provinzen Hessen-Nassau und Rheinland etc. 1903. "

BELLEVILLE, Ont.—Provincial Assay Office. Monthly Bulletin, No. 32, 1902. *The Office*

BERNE—Département de l'Interieur de la Confédération Suisse, Section des Travaux Publics. Tableaux graphiques des Observations hydrometriques suisses et des températures de l'air et des hauteurs pluviales pour l' anné 1901. *The Department*

BIRMINGHAM—Birmingham and Midland Institute Scientific Society. Records of Meteorological Observations taken at the Observatory, Edgbaston, 1902 by Mr. Alfred Cresswell. *The Society*

BIRMINGHAM—*continued.*

Birmingham and Midland Institute. Programme for Session 1903-4. *The Institute*

Birmingham Natural History and Philosophical Society. Proceedings, Vol. XI., Part ii., Session 1901. *The Society*

BOLOGNA—R. Accademia delle Scienze dell' Istituto di Bologna. Memoriè, Serie 5, Tomo VIII., 1899-1900. Rendiconto delle Sessioni, Nuova Serie, Vol. IV., 1899-1900. *The Academy*

BONN—Naturhistorischer Vereins der Preussischen Rheinlande, etc. Verhandlungen Jahrgang LIX., Hälfte 1, 2, 1902. *The Society*

Niederrheinische Gesellschaft für Natur- und Heilkunde. Sitzungsberichte Hälfte 1, 1902. ,,

BOSTON, Mass.—American Academy of Arts and Sciences. Proceedings, Vol. XXXVII., No. 23; Vol XXXVIII., Nos. 1 - 25, 1902-3. *The Academy*

Boston Society of Natural History. Proceedings, Vol. XXX., Nos. 3 - 7, 1902; Vol. XXXI, No. 1, 1903. Memoirs, Nos. 8, 9, 1902-3. *The Society*

BOULDER, Colo.—University of Colorado. The University of Colorado Studies, Vol. I., Nos. 1 - 3, 1902-3; Vol. II., No. 1, 1903. *The University*

BREMEN—Meteorologische Observatorium. Deutsches Meteorologisches Jahrbuch für 1902, Jahrgang XIII. *The Observatory*

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PROCEEDINGS

OF THE

ENGINEERING SECTION.

PROCEEDINGS OF THE ENGINEERING SECTION.

(IN ABSTRACT.)

IN accordance with the resolution passed on 15th October 1902, the ordinary monthly meetings of the Section were abolished, and in lieu thereof, sessions extending over two or three evenings were adopted, each session being devoted to the consideration of only one subject: it was thought that if the attention of members was concentrated upon one subject for two or three evenings, more papers would be forthcoming and good discussions would ensue.

First Session opened 20th July, 1903.

Mr. S. H. BARRACLOUGH in the Chair.

Present forty-one members and many visitors.

The Chairman announced the death of Mr. T. R. FIRTH, M. Inst. C.E., Engineer-in-Chief for Existing Lines, and expressed on behalf of the members of the Section their sense of the great loss sustained by the Society and the profession of which Mr. Firth had been a distinguished member for many years.

The Chairman introduced the question of Water Conservation and Irrigation as the subject for the session in an address which dealt with its importance and magnitude, and the necessity of special training for engineers in hydraulic science.

Mr. H. G. MCKINNEY read a paper entitled "Water Conservation and the equitable distribution of water for Irrigation and other purposes."

Mr. GEO. CHAMIER read a paper entitled "Property in Water."

The Hon. Secretary read the following papers in the unavoidable absence of the authors:—

"An Economic Aspect of Artesian Bores," by Mr. JAMES W. BOULTBEE.

"The Measurement of the Flow of Streams and Artesian Bores as carried out by the Public Works Department of New South Wales," by Mr. H. S. I. SMAII.

The session then adjourned.

First Session continued 22nd July, 1903.

Mr. S. H. BARRACLOUGH in the Chair.

Present sixty-five members and many visitors.

The Chairman announced with deep regret the death of Mr. F. LLOYD.

Professor HASWELL's paper entitled "The question of the occurrence of living organisms in the Artesian Waters," was read by the Hon. Secretary in the unavoidable absence of the author.

Mr. WADE read a paper entitled "A Review of Water Conservation in New South Wales."

Mr. KNIBBS read a paper entitled "The Hydraulic Aspect of the Artesian Problem."

Mr. ROOKE read a paper entitled "The relation of Electricity to Irrigation and Land Development."

The session then adjourned.

First Session continued 23rd July, 1903.

Mr. S. H. BARRACLOUGH in the Chair.

Present thirty-five members and several visitors.

The President of the Society, Mr. F. B. GUTHRIE, read a paper entitled "The Chemical Nature of the Soils and Artesian Waters of New South Wales."

Mr. J. H. McColl, M.H.R., addressed the meeting upon the question of Water Conservation and Irrigation in Victoria.

Discussion of the papers read was opened by the Chairman and continued by Messrs. Benbow, Cardew, Fuller, Chamier and Wilson.

The session then adjourned.

First Session continued 24th July, 1903.

Mr. S. H. Barraclough in the Chair.

Present, His Excellency the Governor of the State, ninety members and many visitors.

The Chairman welcomed His Excellency as the Representative of His Majesty the King and as a Vice-Patron of the Society, and expressed the appreciation of the members for his presence.

Professor David read a paper written jointly by himself and Mr. Pittman entitled "Irrigation Geologically Considered, with special reference to the Artesian Waters of New South Wales," accompanied by many interesting diagrams, exhibits and specimens, and illustrated by lantern slides.

Mr. R. T. McKay read a paper entitled "The River Murray," illustrated by lantern slides.

Mr. Cardew moved a vote of thanks to the authors of the papers, which was seconded by Mr. Davis and carried unanimously.

The session then terminated.

Second Session opened 18th November, 1903.

Mr. S. H. Barraclough in the Chair.

Present thirteen members and two visitors.

The Chairman explained that owing to various causes it had been found necessary to postpone the Session on "Scientific and Industrial Education in Australia" until the following year.

The Committee for the ensuing year was elected as follows:–Chairman, S. H. BARRACLOUGH, M.M.E., Assoc. M. Inst C.E., Hon. Secretary, J. HAYDON CARDEW, Assoc. M. Inst. C.E. Committee: C. O. BURGE, M. Inst. C.E., G. R. COWDERY, Assoc. M. Inst. C.E., J. DAVIS, M. Inst. C.E., HENRY DEANE, M.A., M. Inst. C.E., T. H. HOUGHTON, M. Inst. C.E., M. I. Mech. E., R. T. McKAY, C.E., J. N. C. MACTAGGART, B.E., HERBERT E. ROSS, P. W. SHAW, Assoc. M. Inst. C.E., J. TAYLOR, B.Sc., A.R.S.M. Past Chairmen: NORMAN SELFE, M. Inst. C.E., M. I. Mech. E., J. M. SMAIL, M. Inst. C.E., H. G. McKINNEY, M.E., M. Inst. C.E.

Mr. C. O. BURGE read a paper on "High Speed Electric Railway Trials on the Berlin Zossen Line 1901, 1902, 1903," which was discussed by Mr. BRAIN, Electrical Engineer to the Railway Commissioners, and by Messrs. ROSS, COWDERY CARDEW, and the Chairman.

Mr. PERCY ALLAN, then exhibited lantern slides of the Pyrmont Bridge, and described the principal features of the bridge and its construction for which he was accorded a hearty vote of thanks.

The session then terminated.

INTRODUCTORY REMARKS.

By S. H. Barraclough, B.E., M.M.E., Assoc. M. Inst. C.E.,
Chairman of the Section.

[*Delivered to the Engineering Section of the Royal Society of N. S. Wales, July 20, 1903.*]

Gentlemen,—As this is the first meeting of the Engineering Section since the election of the new committee, I take the occasion to thank you most sincerely for the high honour you have done me in electing me to preside over the Section during the present session. Election to such a position, although involving considerable responsibility and demanding a fair expenditure of time and labour, can only be regarded as a privilege, and I am glad of the opportunity of expressing my warm appreciation of this token of your confidence and kindly esteem.

My satisfaction is distinctly enhanced by the fact that, for the present session, circumstances have relieved me of the necessity of imposing upon you the customary address from the Chair. The reasons for the postponement of the address till the next session are fairly obvious from the business paper which is before you. I would do nothing to lessen the importance or detract from the dignity of the post, but your committee agreed with me that, in view of the large number of papers to be presented at this session, all of them more or less bearing on one topic, it would be more judicious to have the Chairman's Address at the October Session, particularly as my remarks will be more germane to the subject of "Technical and Industrial Education in Australia," which it is proposed to discuss at that session, than to that now before you.

I have, in the next place, to extend a cordial welcome to the representatives of kindred associations and to other

visitors who, by their presence this evening and during the week, support us in our project of holding a more or less continuous conference, at which a large number of papers are read and discussed, as a substitute for the hitherto customary plan of a regular monthly meeting with one or two papers at each meeting. It must be left to subsequent events to show whether or not the innovation will suit the conditions of the Engineering Section, and overcome some difficulties which have beset us during the last two or three years.

Although the Royal Society had its origin as far back as 1821, it was not till 1891 that its Engineering Section was inaugurated with Mr. Cecil Darley, M. Inst. C.E., as its first Chairman, and Professor Warren, M. Inst. C.E., as its Honorary Secretary. The Section has thus already completed its twelfth year of activity, and in view of the large number of valuable papers it has published and the field it has offered for the discussion of professional and scientific engineering questions, there is probably no exaggeration in saying that it has already played an important part in the community and earned its right to public esteem.

Our nominal roll of members at present stands at slightly over 100 names, and to these the notices and other printed matter bearing on the meetings have hitherto been posted month by month. It is to be regretted that a larger proportion of these members does not attend regularly. In a community like our own, where the number of those engaged in professional and scientific pursuits is naturally small, the maintenance of institutions such as this in a state of efficiency, must inevitably call for a certain amount of sacrifice from the members. During the past couple of years the difficulty of obtaining a satisfactory attendance at the meetings has been more marked, and after a full discussion of the matter by the Section towards the end of

last year, it was decided to adopt the present scheme as probably being more likely to suit the convenience of members. The details of the plan were left to the discretion of the committee, and any suggestions for future sessions, which members may be able to offer as a result of this week's experience, will be welcomed by the committee.

Probably no explanation is needed as to our choice of a subject for discussion at the first Session. It is now generally recognised that an assured and sufficient, even if not liberal supply of water in all years, is an essential factor in the complete achievement of the country's industrial possibilities, and the community at large is coming to be alive to the importance and wisdom of undertaking such works of water conservation and irrigation as may ultimately attain this end. The problem is admittedly a large and difficult one. The area of country to be dealt with is so enormous, the quantity of water so limited, and the conflicting interests involved so various, that a complete scheme of water conservation and distribution is not to be quickly arrived at. The preparations for so great an undertaking merit therefore the most careful consideration, and it was thought that no more suitable subject could be selected for the deliberation of the Section.

I do not propose to trench upon the subjects to be discussed by later speakers, but before sitting down I wish to refer in a word or two to the question of the education and training of those who are to engage in this enterprise.

That leading colleges and universities in America should find it advisable to inaugurate systematic courses of instruction in irrigation-engineering is most noteworthy, first as an obvious evidence of the importance which attaches to the whole subject in that part of the world, and secondly as showing the distinct effort which has been made to meet

the requirements of the situation. Professor Elwood Mead (Professor of the Institutions and Practice of Irrigation in the University of California, and Chief of Irrigation Investigations in the United States Department of Agriculture) says[1] in this connection—"The most important industrial problem of the western part of the United States is the distribution and control of water used in irrigation."

The cheap labour of China, India, and other irrigating countries of the past is not available in America or here in Australia. Skilful engineering and agriculture must therefore compensate for the high price of labour. Systematic instruction in this subject might presumably be given either in connection with a course in agriculture or in civil engineering, but preferably the latter.

In the United States there are numerous Engineering Schools already giving more or less complete courses of training in irrigation engineering. The pioneer in this work was the State Agricultural College of Colorado. The latest is the University of California. The instruction in the last named institution extends over the usual undergraduate period of four years, the subjects taught during the first two years being identical with those of the regular civil engineering syllabus, while the special studies in connection with irrigation are introduced during the third and fourth years.

This particular course of instruction aims at training the engineer rather than the agriculturalist, but it is a point worthy of some emphasis that if we intend to embark on large schemes of water conservation and irrigation it will be equally necessary for us to specially train the farmer in the art of applying the water to the land. At present very little is done in either direction, but the moral to be drawn

[1] Proc. Soc. Prom. Eng. Ed., Vol. x.

from the example of Western America is too obvious to be missed. A good opportunity of providing the necessary instruction will occur if the proposal to establish a Chair of Agriculture at the University of Sydney is realised. The courses offered by such a department of the University, together with those already available in Civil Engineering and Surveying would probably serve the need admirably.

WATER CONSERVATION AND THE EQUITABLE DISTRIBUTION OF WATER FOR IRRIGATION AND OTHER PURPOSES.

By H. G. McKinney, M.E., M. Inst. C.E.

[*Read before the Engineering Section of the Royal Society of N. S. Wales, July 20, 1903.*]

As this paper is the first of a series on the subject of water conservation and irrigation, it appeared the most suitable course to give it an introductory character, and to furnish a brief outline of the natural conditions bearing on the subject.

Referring to a map of New South Wales showing the main watersheds, and outlining approximately the extent of the effective and the non-effective portions of the catchment areas, the great difference in character between the country west of the Dividing Range and that on the east is easily understood. The fact that the main watershed along the Dividing Range is only about 70 miles, on an average, from the coast, is sufficient to indicate that the coastal rivers are comparatively short, and their rate of declivity great. Examination of the rainfall records show that throughout the whole of the coastal district there is

a good average rainfall, that very heavy falls of rain occur frequently on some of the catchments and occasionally on the others, and that considerable periods of dry weather are of common occurrence. Taking these points in conjunction with those already mentioned, we naturally find that the coastal rivers are liable to great floods of short duration, and that there are often long periods of low supply. It is owing to the former characteristic—that is the great height and destructive character of the floods—that the subject of flood prevention has been one of much importance on the Hunter and the Clarence, while the results of the long periods of low river have been brought home to the people of Sydney by the condition of their water supply.

The large number of rivers, creeks, and natural waterholes throughout the coast district, and the fairly satisfactory average rainfall combine to make the conservation of water, for other than town supply, mining, and manufacturing purposes, a question of easy solution. The generally uneven character of the land, taken in conjunction with the fair average rainfall, renders irrigation on an extensive scale impracticable. But it has been proved in a number of cases, that irrigation of orchards and also of lucerne and other fodder crops can be carried out with advantage on a moderate scale, and an increase in the number of such cases may reasonably be expected.

The question of flood prevention on the Hunter is one of much importance, and has been investigated time after time for more than thirty years, and although various steps have been taken to mitigate the risk, the question is far from being settled. If the facilities for impounding flood water on an extensive scale had been as favourable as those existing on the Clarence, it is not improbable that something would have been done with this object long ago.

The conditions of the rivers which flow westward from the Dividing Range can be seen from the map alone to be in complete contrast with those of the rivers which flow to the east coast. While the courses of the latter are short and their declivity rapid, the former have to flow many hundreds of miles before their waters reach the river Murray, and hundreds of miles further before they reach the ocean. The catchment areas of these western rivers gradually become less effective till their waters reach the great central plains of the State, which so far from being a catchment area in the ordinary sense of the term, might fairly be described as a great depleting area. The rainfall also diminishes as the distance from the Dividing Range increases, so that the country which has the greatest need for water and which is best fitted for its distribution and its use for irrigation is the place where there is a diminished and diminishing supply in the rivers. The courses of these rivers through the great central plains are tortuous, and with the solitary exception of the Murray, they become shallower and more contracted, with their distance from the Dividing Range, till in some cases, as for instance the Lachlan, the Macquarie, and the Gwydir, they cease to exist as defined rivers. The result of these conditions is that when the rivers are low the lower landholders frequently receive no water whatever, and when the rivers are high the lower lands are inundated to the extent of many hundreds of thousands of acres. This flooding of the lower lands on the rivers of the Central and Western Divisions of the State is generally very beneficial. It is, in fact, natural irrigation on an extensive scale, but the economic results viewed from a national standpoint are unsatisfactory in the last degree. That large areas of pasturage are greatly benefited by the flood waters is beyond question; but on the other hand it has to be borne in mind that in producing this pasturage there is a deplorable waste

of water and that this waste occurs in districts where water has its greatest value. Extensive areas are flooded to such a depth as to kill vegetation, useless swamps are converted into great evaporating pans, and innumerable lagoons and shallow channels which are practically useless for storage purposes contribute to the general waste. These are the conditions which prevail whenever any considerable flow reaches the lower parts of such rivers as the Lachlan, the Macquarie, and the Gwydir, and in a less degree in the cases of other rivers. It is extremely doubtful whether the area of pasturage which is materially benefited represents one-tenth of the irrigating capacity of the water which disappears.

The great difficulty which presents itself at the outset in establishing a proper basis for dealing with rivers of this description lies in the fact that the lower holders who possess undoubted rights have generally very crude ideas as to how these rights should be preserved. Some of them still object to all works without distinction which are constructed on the river above them. This idea is, however, dying a natural death, and its disappearance is being hastened by the fact that both in this State and Victoria there are standing instances of the manner in which a creek or a river can be improved for the landholders throughout its entire length by the construction of suitable works. As regards our typical rivers, there are hundreds of thousands of acres of fertile land through which these rivers flow and in which the irrigation of moderate areas at intervals would be of incalculable benefit. The question to be solved is how to utilize the waters so as to benefit these lands without injury to the interests of the lower holders who depend on periodical floodings.

The principle on which this question can be solved is less difficult than might at first sight appear. Whilst floods of

moderate height and duration give rise to much benefit to the holders of the lower lands, high floods and floods which stand long on the land are frequently the cause of serious loss and inconvenience. Another serious source of loss with which the lower holders have to contend is the occasional failure of the supply in the river. Unfortunately this is not an uncommon occurrence, and on such occasions the supply of water even for stock and domestic purposes is limited and unsatisfactory. It is thus obvious that if measures can be taken which will diminish the height and shorten the duration of high floods and will also ensure a better supply of water during periods of low river, the position of the lower holders will be materially improved. That such measures, which will benefit both the lower and the upper landholders can be taken, is not a matter of mere theory but an ascertained fact. The best instances of the system to which I refer are furnished by the Colombo Creek in New South Wales, and the Wimmera River in Victoria, the former being typical of the system as applied to a creek of a character common in the Central and Western Divisions, and the latter being illustrative of the system as applied to a river like the Lachlan, the Macquarie, or the Gwydir.

The Colombo Creek, which is an outflow creek from the Yanko, has a system of dams so complete that in some cases the water held back by one dam extends to the base of the dam next above. The dams have good natural bywashes which carry on any ordinary flow. The result of this state of affairs is that the bed and banks of the creek are always more or less saturated, and that in consequence when a freshet enters the creek it flows through more quickly than formerly, even when the levels of the water held back by the dams are exceptionally low. This of course indicates an improved condition throughout the whole length of the creek.

The conditions originally existing on the Wimmera River closely resembled those on several rivers in the Central and Western Divisions of this State, so that when the construction of dams and weirs on it was first undertaken an outcry was raised by the holders of the lower lands. This outcry was increased when the improvement of natural outflow channels and the construction of new outflows was initiated. It proved, however, that the apprehensions were groundless, and that the system of improvements made was practically an unmixed benefit to a large district. The results of the works carried out were that a permanent supply of water was stored in the river by the weirs, that several hundred miles of channels distributed the surplus water throughout the district, and that the lower holders were more equally and more regularly supplied with water than before.

The principles of this system can be and should be followed on most of our western rivers, and particularly on the Lachlan, Macquarie, Namoi, and Gwydir, and on the numerous creeks of the Central and Western Divisions which afford suitable conditions for conserving water. What is wanted in all such cases is a complete series of weirs or dams to conserve water for stock and domestic purposes where the supply is small, and for irrigation where the conditions are sufficiently favourable, and outflow channels and pumping stations at intervals to utilize the surplus waters to the greatest advantage. The construction of numerous weirs in the rivers would ensure a more regular and more equable supply to the lower holders, and would thus encourage them to make distributary channels to supersede the present wasteful arrangement of leaving everything to nature.

With regard to the depth of water which may be allowed to be held back by weirs and dams in our creeks and rivers,

it became the duty of the present writer over six years ago to prepare a statement of conditions under which licenses in terms of the Water Rights Act might be granted for such works. The general rule which was proposed and approved of in regard to the maximum height of weirs or of the bywashes of earthen dams, was that this should be limited only by the condition that sufficient waterway should be left above the weir or above the bywash to pass on any ordinary flow in a river or creek without causing inundation of adjacent lands. This rule was deemed suitable for the great majority of cases, and nothing has transpired to show that its effect is other than beneficial. If a series of weirs subject to this condition were constructed on such rivers, as the Lachlan and the Namoi, and the waters were utilized to the utmost by means of pumps and outflow channels, it might then be considered that these rivers were fairly turned to account. All that would then be required further to give steadiness and security to the use of the river waters would be the construction of storage reservoirs on the higher parts of the catchments. Such storage reservoirs would provide the means of using the winter flood waters to maintain a moderate flow during the summer months.

There is a branch of this subject which is of much greater importance than might at first sight appear. This is the serious harm which is being done by earthen dams which have faulty bywashes. To appreciate the extent of the mischief done in this way, it is necessary to realise that in the Central and Western Divisions there are hundreds of dams with natural bywashes, that these dams are of vital importance for providing water for stock and domestic purposes throughout a large proportion of the area of these districts, and that these bywashes are frequently carried away to the serious injury of the channels below them. To

explain the position more fully, it may be stated that throughout the central and western districts of this State nearly all the rivers and creeks are intermittent in their flow, and that their courses, where the conservation of water is of the greatest importance, generally lie through deposits of alluvium. Creeks and flood channels having depths of from seven or eight feet to twenty feet and widths ranging from twenty feet to a hundred feet are very numerous, and as their rate of fall is often not more than a foot in a mile, the value of these channels for conserving water is at once obvious. Flood channels which have been formed by overflows from these creeks, and sometimes old channels in which the creeks formerly flowed but which have in a great measure been silted up, are used as the bywashes in connection with earthen dams. But it frequently happens that the concentration of the flow in these secondary channels has the effect of eroding and enlarging them till their beds are brought down to the levels of the creeks, so that the dams cease to have any useful effect. It then becomes necessary to construct a new dam across the bywash, or to extend the old one with the same object. Cases of this kind where the original dam has been extended time after time till its length exceeded a quarter of a mile are not uncommon, and some are to be found where the length is much greater than this. The worst feature in connection with incidents of this character is that the earth eroded from the bywashes is carried into the creeks below the dams. The natural process by which the channels of the creeks and rivers are being silted up is sufficiently serious to merit careful attention; but this process has been greatly accelerated by two causes, both of which were in a great measure preventible. The first was the wholesale destruction of useful shrubs such as the saltbush, and of trees such as the boree and the myall, and the consequent increase in the destructive effects of dustorms.

The second was the defective system described in connection with the construction of many earthen dams. With all these contributing causes at work, it is not surprising that in many instances creeks have greatly diminished in value on account of the smaller storage capacity which they afford.

It might be supposed that the expense and trouble which landholders incur through failure of unsatisfactory bywashes in connection with earthen dams, especially as it is not uncommon to find that the expense incurred on account of such a work exceeds the cost of a suitable overshot dam, would bring about an effectual remedy. Unfortunately the lessons learnt by such experience are sometimes very slow in producing their effect, and it seems not unlikely that in some cases at least, the substitution of overshot dams will not be decided on till the further question arises as to whether the storage capacity still left is sufficient to warrant the expense of constructing a dam of any kind.

From what has been stated it is obvious that while much discrimination is necessary in regard to the conditions under which licenses for dams and other works on rivers and creeks should be granted, every encouragement should be given to the construction of all such works as comply with these conditions. These works require to be regarded not merely as being intended for the benefit of the persons who construct them, but as part of a system which should be beneficial as a whole. The question of river conservancy is one of great importance, and the best results can be obtained only by following a carefully considered and comprehensive system. In the case of the Gwydir River, an area of about half a million acres of fertile land is rendered practically useless in wet seasons, so that for the time, drainage becomes a much agitated question. When a prolonged drought occurs, the pressing need is for irrigation

in and near this same area, and this is only one of a number of instances of the same character. The immediate aim of systematic administration in such cases should be the limiting of the depth and duration of the flooding in wet years by the conservation and the wider distribution of the waters which are now wasted on a gigantic scale. This could be done to the advantage of all concerned, by the construction of storage reservoirs, dams, and outflow channels, the effect of which as already indicated, would be to give a widely distributed supply of water throughout the course of a river, while affording a better regulated and less precarious supply to the lower landholders.

PROPERTY IN WATER.

By GEORGE CHAMIER, M. Inst. C.E.

[*Read before the Engineering Section of the Royal Society of N. S. Wales, First Session July 20, 1903.*]

PROPERTY in water is naturally vested in the possession of the land, upon which, for the time being it lies. Whether falling as rain, or running from springs at the surface, or being drawn from wells under the earth, the water belongs to the landowner, who has exclusive disposal of it, so long as it remains upon his land. This is a self evident proposition, for it would be impossible for any civilized community to manage otherwise, as water is essential for cultivation and industry, and must be owned, preserved, and utilized for the indispensable needs of man.

Thus the principle of property in water is established in the nature of things: it is universally received and embodied

in the laws of most nations. Law, we are often told, is Common Sense. It should be so, at least, in essentials; and it is upon the basis of common sense and practical requirements, that it is proposed to deal with the subject in this paper. It has been asserted, indeed, in one of those legal definitions that define nothing, and only lead to useless discussions, that water, like air, is common property, and should not be absolutely appropriated by anyone to the detriment of the public interest; but it is beside the question to argue about abstract rights: exclusive possession is quite enough for all practical purposes. Water in the clouds, may be for aught the writer knows, common property, but as soon as it descends as rain and runs off a man's roof into his tank, it becomes just as much that man's private property, as anything else in his possession. The rain-water that falls on private land may be impounded and utilized in any way the proprietor may deem fit. Nobody else has any claim to it. Most of the undertakings for the water supply of towns and industries in Europe and America have been carried out on this undoubted principle. Catchment areas have been purchased for the purpose, impounding reservoirs have been constructed, and the water afterwards disposed of like any other commodity. But although the landowner may justly claim possession of the water lying on his land, he has not the same exclusive right to water flowing in a defined channel, through, or by his property. In that case he must share his claim to the use of the water with all the other proprietors of land along the course of the stream, for they have equal rights to participate in the benefit. Thus, running water, in a well defined watercourse, becomes, not public property, but the common property of the riparian owners along its banks.

This is the basis of the Law of Riparian Rights, which, although so troublesome and complicated in some of its

developments, is yet very simple in its essence, and appears to be universally acted upon. The general principle is that all riparian proprietors are entitled to the "reasonable" use of the stream for domestic and industrial purposes, for stock, and all other ordinary requirements. The water may even be diverted for irrigation, provided a sufficiency is left in the stream to meet all other reasonable demands. A proprietor may also dam up a water course, within his own land, and utilize the water for mechanical purposes, as in the case of mills, but only so far as not to materially diminish the ordinary flow, or to occasion damage or inconvenience to other riparian owners. The principle is therefore established that the water of a stream is the property of the riparian landowners, collectively. Under combined action they may exercise entire control, and divert or utilize the stream in any way they may deem fit. Wherever a State has taken over these collective riparian rights by Statute, it is evident that all such powers devolve upon the State.

This is an important point to bear in mind when defining the right of a State to the tributaries of a main river within its own territory. The only exception to the rule is in the case of a large river which is open to regular navigation, and is held to be a main highway for public traffic. This may introduce complications, which will be dealt with later on. It does not appear that the extent of frontage to a river gives the landowner any additional claim to the water. A proprietor possessing many miles of river bank has only the same right to the "reasonable" use of the stream as the holder of a cottager's allotment. The right is on the "one man one vote" principle—all share alike in the privilege. Neither does the ownership of the bed of a "defined" watercourse carry with it any special right to the stream. This rule is general in its application: it will

hold for a State as for a private individual. Here, in Australia, we have an important case in point. The entire bed of the Murray, as far down as the South Australian border, belongs to New South Wales. The boundary of this State extends to the river bank on the Victorian side, but this fact does not afford New South Wales any special right or superior claim to the river water. The stream of the Murray is common property to the three States, by or through which the river flows. They all have equal claims. Nor does the fact that one State contributes more than another to the quantity of water flowing in the river, make any difference, because, once the water reaches the river it becomes an integral part of the river, and common property. There is no "give and take" in riparian rights.

The rights of riparian proprietors are subject to one important limitation. They only apply to the ordinary or normal flow of the river. Flood waters are held to furnish a "surplus" which may legitimately be drawn upon for purposes of general utility. There is no recognised vested interest in floods. It is upon this established public right to surplus water, which most rivers bring down during certain seasons, that many important undertakings for water conservation have been carried out. Immense quantities of water may thus be diverted or impounded without infringing any right, and where a State has obtained by law the control of all public watercourses there does not seem to be any limit to its right in diverting or conserving flood waters. Of course there are some peculiar cases where this rule might not fairly apply, and in some countries, like lower Egypt, nearly all the benefit derived from a river is through its floods, but then there are no rules without exceptions, and a law may need to be modified to meet the common interests involved. In a general way, however, it may be taken that the law of riparian rights does not apply to floods.

We have next to consider the question of navigation rights, as affecting the use of rivers and property in water. According to British Common Law the public right of navigation only extends to tidal water. There is no public franchise for navigating rivers beyond that limit unless acquired by prescription or granted by some special Act. As a rule, according to English law, a river is held to belong to the riparian proprietors collectively.

On the continent of Europe and in America the right of navigation is more general, and applies to all the large streams that are available for regular and permanent traffic. In those countries the great rivers form arteries of communication to the interiors of continents, between different States or distinct nations. They possess, therefore, an inter-State or international character.

The right of navigation will naturally debar anyone from obstructing the traffic. Thus all weirs across a navigable river have to be provided with locks for the passage of boats. Apart, however, from a claim to unrestricted traffic, such as the condition of the stream may permit, the right of navigation involves no sort of property in the water or control of the stream. Riparian rights are therefore not affected as far as the "reasonable" use of the water is concerned. It is questionable if any State or private company would have the right to divert such a large proportion of a navigable river, as thereby to render the stream unnavigable. Where a river is regarded as a main thoroughfare, and involving inter-State or international interests, any such diversion would be an infringement of established rights, and clearly a wrong. Every State, however, has the full control and disposal of the tributaries of a main river, within its own territory, nor would any such restriction apply to flood waters.

As a main river usually derives most of its volume from tributaries along its course, it might be argued that the

absorption of these feeders, for irrigation or other purposes, might so diminish the natural flow of a navigable river as to render it unnavigable, and thus inflict a serious and unjustifiable injury to vested interests. But according to the fundamental principles of property in water, already explained and universally admitted in law, the primary right to the water is appurtenant to the ownership of the land.

A river is a natural outlet for *waste* water—that is, for water that has not been utilized and has been allowed to escape off the land. The interests of navigation are therefore secondary, and there is no injustice involved. As regards the sources of a large river they could not be materially affected, as they are always so situated as to render their diversion impracticable. Issuing from high and often snowy ranges, or from dense forests and broken ground, they cannot be tapped or impounded, and it is only the tributaries that debouch on the plains that admit of being utilized for water conservation or agricultural purposes. Looking at the matter from a practical point of view, it is only in rare cases that the utilisation of water can, in any way, interfere with the navigation of a main river, but where such a conflict of interests may arise, it is evident that the right of navigating cannot affect the claim of the land to the water, before it enters the stream. If we now apply these principles to the conditions obtaining in Australia, we are led to certain definite conclusions, that are of great importance, not only as affecting local interests, but also the welfare and progress of three of the principal States.

Australia differs in two particular respects from most other civilized countries; first, as regards physical conditions which have denied to this continent any great rivers, or an ample water supply. Not only is the volume of its

principal streams very small, in comparison with the enormous watershed they drain, but the flow is intermittent, depending largely on a most uncertain rainfall. The consequence is that inland navigation is precarious and much restricted, while the quantity of water available for irrigation is so limited as to need the utmost economy in its use. It follows that in this country as little water should be allowed to flow to waste as possible, but this useful work may bring about such a diminution of the flow in the main rivers as to unfit them for navigation at certain periods. Thus a conflict of interests is imminent.

Secondly, another important difference lies in the system of government control, exercised over all works of development and of a public character. In Australia the State has assumed certain rights over water-courses, which generally appertain to riparian owners, acting collectively, and it is invested with full powers over the streams that flow within its own territory.

This law is beneficial in simplifying intricate claims relating to riparian rights, and it facilitates the carrying out of irrigation works of a national character, while it does not affect the main question of property in water. The rights of landowners to the streams are only, to some extent, vested in the State for the public advantage. But such powers do not extend over inter-state rivers, which are common property to all the States affected, and especially in what concerns river navigation.

Now, as regards this question of navigation, it is clear that it can only concern rivers which are, in a reasonable sense, navigable—available for regular traffic. Where a river is considered a highway for inland communication it must be adapted for such a purpose, if not at all times, at least within reasonable limits. In the proper sense of the word, none of these streams, with the exception of the

Lower Murray are navigable rivers. But still a certain amount of river traffic has been maintained in the past, and certain vested interests have arisen, that will have to be duly considered. The river Murray as far as Wentworth, is generally navigable for steamers of light draught for about nine to ten months in the year; the Upper Murray to Mildura is only available, on an average for six months, while in the higher reaches to Albury, the river is barely open for traffic for more than five months and often for a less period. The Murrumbidgee, is not, strictly speaking, navigable at all, as beyond Balranald it is often entirely closed to river traffic for a whole year. The Darling has been dry for twelve months at a time, but during some years it has carried regular traffic, which has been of great use to remote settlements along its banks. The question of its navigation, therefore, cannot be entirely neglected. These rivers are all subject to periodical floods, and it is only at certain times of the year that the withdrawal of water from the Murray for irrigation could affect its navigation. Victoria, by several works in operation, already draws a considerable quantity of water from this river. Some important undertakings in prospect would absorb much more.

New South Wales has taken practically nothing from the river as yet, but it has a projected scheme for an irrigating canal that would divert a large protion of the stream, and at a time when the water in the river can least be spared. The interests of South Australia are mostly centred in the navigation of the Lower Murray, which might thus be seriously affected, and certainly that State is fully justified in opposing the withdrawal of so large a volume from the river as to cripple an established industry in which it is largely interested.

Viewed on the basis of the principles of law and equity already stated, it is evident that the water flowing in an

inter-State navigable river should not be withdrawn, apart from "reasonable use" of riparian owners, to the detriment of any vested interests in the river. It is no justification for such action to allege that South Australia contributes nothing to the Murray, as it is quite immaterial where the water comes from. It is no justification, as between States, to dwell on the superior importance of irrigation, for the development of the whole community over navigation, which represents a minor and much restricted interest.

Such arguments, though plausible, carry no intrinsic right with them, unless it is the right of the strongest. No doubt, in a question of this sort, if a conflict of public interests became unavoidable and irreconcilable, then the cause promoting the greatest good of the greatest number must eventually prevail, but in this instance there is no necessity for a desperate struggle for supremacy, as simple methods are available for accommodating all differences, and serving both interests without injury to either.

There are two ways by which the navigation of the Murray in South Australia, might be maintained, without hindrance to the projected irrigation from that river:—First, by the construction of large, impounding reservoirs, where sufficient flood water might be stored to supply the deficiency during the dry season, and there are suitable sites for such works. Secondly, by locking the lower river; by which means and at a small expense, the Murray, with South Australian territory, could be rendered permanently navigable, and with a greatly diminished water discharge. Under both these systems, a large volume of water, which now flows to waste, might be utilized with benefit to extensive areas of good land, at present almost valueless for settlement, through lack of moisture.

But in any case there can be no reasonable doubt as to the right of each State to conserve and utilize the water flowing off its own territory. The claim of South Australia can only extend to the normal flow of two inter-state rivers, the Murray and the Darling. The feeders of these main streams are not under any common jurisdiction. Victoria is fully justified in the undertakings already carried out, or proposed, for intercepting the flow of tributary streams, such as the Goulburn or Campaspe, and turning the water on to the land. The great scheme of the Murrumbidgee dam and irrigating canal is entirely within the control of New South Wales. No other State has any right to interfere.

Much has been said in favour of compromise in the settlement of these differences, but even compromise must be based on some general principles. Compromise should never be allowed to over-ride the natural and inalienable rights of a community to one of its most precious resources. Each State should safeguard its own property, which is none the less important because it is only Property in Water.

THE HYDRAULIC ASPECT OF THE ARTESIAN PROBLEM.

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[Read before the Engineering Section of the Royal Society of N. S. Wales, July 22, 1903.]

SYNOPSIS:—

Introduction.—Problem has four aspects (*a*) Geological, (*b*) Chemical, (*c*) Biological, (*d*) *Hydraulic*. Only last considered. I. Nature of the Problem; II. Its indetermination; III. Its importance; IV. Its scientific basis; V. Conclusion.

I.—1. Practical aim to exploit artesian supply.
2. Source of artesian waters.
3. Intake area.
4. Is the condition hydrostatic or hydraulic?

II.—1. Hydrokinetic foundations of the problem.
2. Its general indetermination.
3. Unknown factors therein.
4. Complication by existing facts.

III.—1. Importance of the problem generally.
2. Danger of passing to the subartesian condition.
3. Economic effect thereof.
4. Necessity for scientific investigation.

IV.—1. Steady and turbulent flow.
2. Flow in capillaries.
3. Conditions of flow in sand and rock.
4. Experimental investigation.
5. Theoretical investigation.
6. The lines of flow.
7. The curve of pressure.
8. Complexity of probable actual condition.
9. Thermal and other conditions.
10. Fluctuations of pressure; theoretical considerations.
11. Investigation of fluctuation of flow.
12. Real form of the actual problem.

V.—1. How and when investigation should be made.
2. Necessity for legislative control of frequency of bores.
3. The future of artesian exploitation.

INTRODUCTION—There are four very different aspects to the artesian problem, all of which will throw light upon its practical solution, viz., the (*a*) *Geological*, (*b*) Chemical, (*c*) Biological, (*d*) *Hydraulic*. All are important, and in any thorough investigation of the question, none can be omitted. For the key to the solution may happen to lie in a suggestion coming from any quarter, and no one who has seriously studied the problem will hesitate to avail himself of every clue to its solution. Notwithstanding this, the problem is fundamentally a geological-hydraulic one. The hydraulic aspect is that which is considered in this paper.

I.—NATURE OF THE PROBLEM.

1. *Practical aim to exploit artesian supply.*—A large supply of underground water beneath the level surface of an arid region, means the possibility of considerable economic development. If the supply be *certainly* continuous, the places where it is tapped are nuclei of safety at critical times of drought, etc., and may be made also, centres of intense cultivation, so that if it be possible by proper control of the artesian wells to ensure that the supply shall be *permanent*, even at a very limited number of stations, this control is important.

2. *Source of artesian waters.*—In some parts of the world the source of supply of artesian areas is well-determined, and the rainfall and intake-area admit of a fairly definite opinion being formed as to how far exploitation may be pushed.

The question of *source* is necessarily largely a question of *geology*; but it may be pointed out that it is also one for the hydraulician. If the absolute heights to which the water will rise, are known at every point where the artesian water is tapped, considerable light is thrown on this question, and the geologist certainly assisted in reaching a

definite decision in regard thereto. It becomes however, complicated unless the heights are ascertained initially, as will hereinafter appear.

3. *The intake area.*—The exact location of the intake area as a factor in the solution of the problem, is of course extremely important, for the reason that if its minimum height be determined, it will at once shew what the greatest hydrostatic head available is; that information together with the volume and rate of efflux from the various bores, will go far towards revealing the condition in respect of motion, of the water in the artesian strata. The ascertainment of the extent of the intake area is also a weighty factor, since together with the extent of rainfall thereon, it will afford a basis for estimating how far it is safe to exploit the artesian water, without risk of exhausting it. One of the most important aspects of the problem suggests itself in this connection, viz., in what condition is the water in the artesian stratum?

4. *Is the condition hydrostatic or hydraulic?*—Was the water in a state of motion, or quiescent when initially tapped? If, as has been alleged and as seems probable, it was flowing, then the area of the intake and the quantity of rainfall, etc., giving the absolute quantity of water finding its way into the artesian strata, does not afford sufficient information, and the problem becomes greatly complicated, inasmuch as it will be necessary to ascertain the rate of flow or rate of loss through flow, and also the direction of the flow in order to ascertain exactly how far it would be safe to draw upon it by artesian wells. This question would be *partially* soluble, were it possible to know at each artesian well the absolute height to which the water would rise, if the bore be lengthened upwards. But it would *not* be completely solved for reasons hereinafter stated.

II.—The Indetermination of the Problem.

1. *Hydrokinetic elements of the problem.*—Even though initially there were no motion of the water in the artesian stratum, the flow from the bores has now established one and has lowered the original pressure everywhere, by amounts which vary not only with the distance from the point of efflux, but also with the *coarseness* of the rock and its *porosity* and with the *thickness* of the stratum from point to point. The ascertainment of the *lines of flow* assist in enabling an estimate to be made as to whether the strata are thick or thin, which can also be estimated by the phænomena of flow, as the number of bores increase. The uncertainty as to the details of the facts at great depths makes the hydrokinetic elements of the problem indefinite and conjectural.

2. *General indetermination of the problem.*—This may be more fully explained as follows:—If the water in an unpierced stratum is quiescent, the pressure would everywhere be simply the hydrostatic pressure, varying merely with the level of the stratum. If however, the water therein is flowing, then the *pressure depends on the rate of flow*, falling where the velocity is high, and increasing where it is low. Consequently where a body of water is flowing through interstitial spaces in a stratum, local increase in the thickness thereof, is associated with *rise* of pressure, and local thinness with *fall* of pressure, because in the latter case the *potential* energy has been changed to *actual*, *vice versa* in the former. See Fig. 4 hereinafter IV.; 7, 8.

Where the pressure at any point in a stratum is greater than that due to a head of water, equal in height to the distance from the stratum to the surface, an artesian bore will *certainly flow*, but the *rate of flow* will depend upon: (1) The state of the artesian tube, and still more upon

(2) The ***resistances in the stratum*** itself, especially at points near the bore.

The former can be estimated for a new pipe, but hardly for an old one, and it is to be expected that the ***rate*** of artesian flow will *always* shew some reduction, merely from the pipe becoming less smooth through corrosion, deposit, etc.

This can be roughly estimated, but resistances in the stratum must always be somewhat *conjectural.* For they depend upon the *size of the grains*, the *porosity*, and the *thickness* of the stratum. This leads us to the consideration of the :—

3. *Unknown factors in the problem.*—As an hydraulic problem the flow is calculable *a priori* only when the conditions can be definitely specified. But with both the thickness, the coarseness, and the porosity of the stratum all uncertain or non-uniform, the problem does not submit to definite treatment. There is according to Professor Gregory, another element which must be taken into account viz., the earth's internal heat, which he assumes to increase at the rate of about 1° C. for about every 100 feet of descent, an amount which appears to vary greatly from place to place and is rarely as rapid as this.

The following increases of temperature have been recorded, in each case for 1° Centigrade :—

	Feet.		
Cremorne Bore	144	Journ. Roy. Soc. N.S.W., xxvii., 464, 1893.	
Metropolitan Colliery ...	140	,,	(T. W. E. David and
General value?	113	,,	E. F. Pittman)
Sydney Raibon Colliery	168	,,	xxxiii., 223, 1899.
Schladebach Bore, Prussia	117	,,	(J. L. C. Rae,
Astley Colliery, Dukenfield	130	,,	E. F. Pittman,
Ashton Moss Colliery, Manchester	139		and T. W. E David)
Dukenfield Colliery ...	149	,,	,,
St. Gothard Tunnel ...	147	,,	,,
Lansells' Mine, Bendigo, Victoria	200	,,	,,
Przibram Silver Mine, Bohemia	227	,,	,,
Calumet and Hecla Lode Lake Superior, U.S.A.	401	,,	,,

Professor Gregory combats the conventional view (*a*) that the artesian source is the water under *hydrostatic* (or hydraulic?) pressure in a porous bed interstratified between two (relatively?) impermeable beds. He says (*b*) "But in nature artesian wells occur where there are *no tubular spaces*, and where the water works its way along minute crevices and capillary pores," that (*c*) "under such conditions the pressure of water in the higher part of the bed is soon sopped up by the friction against the sides of the channels," (*d*) "and that the hydrostatic head is lost long before we reach the bore." He says, further (*e*) "Artesian flow *is in most cases* due to the earth's internal heat." After pointing out that at a depth of 8,250 feet (?) the water would reach 100° C., but cannot boil on account of pressure, he says (*f*) "If the pressure be *relieved* then the water bursts into steam, . . or it would allow the expansion of the water and the contained gases." . . (*g*) "The artesian bore through the upper impermeable strata *relieves the pressure* . . and accordingly its expansive forces and imprisoned gases compel it to rise to the surface.'"[1]

Professor Gregory's view is, we venture to think, untenable for the following reasons:—

(*a*) The only necessary assumption is *relative* impermeability of the overlying strata.

(*b*) In some artesian wells, in the Sahara for instance, there is biological evidence of fissures occurring: *i.e.*, artesian water may come from either porous beds, or beds in which there are channels of various sizes.

(*c*) *Hydrostatic pressure never disappears by friction*, though its effect may sometimes be *masked* by surface-tension.

[1] Dr. J. W. Gregory, Professor of Geology and Mineralogy, University of Melbourne.—Australian Mining Standard, xx., 26 Dec., 1901, pp. 1002-3.

That the hydrostatic pressure does not so rapidly disappear as is assumed by Professor Gregory, is easily seen when it is remembered that in a uniform stratum the velocity of the water diminishes as the distance from the bore is increased in the ratio r/R, in which r is the radius of the bore, and R the distance of the point considered: that is to say, putting v for the velocity at the bore of radius r, and V for that at the distance R from its centre,

$$V = vr/R \text{.........} (1.)$$

so that even for the smallest bore, say of 3 inches radius, at the distance of one mile the velocity would be only 1/21,120 of its velocity as it entered the bore; or again, a 10-inch bore discharging 1 million gallons per diem, from a 10-foot stratum, would acquire a velocity of about $5\frac{1}{2}$ feet per second across the surface into the bore. At the distance of 1 mile this would involve a velocity of only about $\frac{1}{100}$ *inch* per second.

(*d*) The *rate of loss of hydrostatic head depends upon the rate of flow* and is very small when the velocity is small, as previously explained.

(*e*) That the earth's internal heat affects the question is indubitable, but thât it is *not* the *causa proxima* is equally indubitable, as will appear when it is remembered that the water is not absolutely imprisoned, and that:—

(*f*) The pressure *is never relieved so far as to allow of ebullition.*

(*g*) Hence the statement in (*g*) above is inaccurate.

4.' *Complication by existing facts.*—The problem of exactly determining the possible flow by tapping the artesian stratum at various points, and of reaching something like definite knowledge of the extent of *safe* exploitation, is greatly complicated by the fact that the *hydraulic records* of the bores (where such records exist at all) are

very imperfect. The measured or estimated yields may be sufficient for general purposes, but it will hardly be claimed that they are adequate for exact deductions. Had *exact* hydraulic records been kept from the first opening of the bores, the attempt to reach a conclusion would have rested upon a much more secure foundation.

The initial circumstances as regards fall of pressure are of special value; so also are the initial records of the influence of adjacent bores. By alternate partial or wholly shutting down of bores it is not difficult to ascertain what these reactions are, and such a proceeding could be made to throw much light upon the problem. As successive bores, however, are opened, its complexity naturally increases, and unfortunately we have badly missed our *initial* opportunities, and to a large extent have been working in the dark, and not only so, but also adding difficulties to the solution.

III.—Importance of the Artesian Problem.

1. *Importance of the problem generally:*—If under any given condition the artesian supply is certain and continuous, or at the worst subject to only relatively small fluctuations about a mean value, the exploitation to an extent which maintains permanency is indicated as desirable, for the reason earlier set out, (See I., 1). In other words the *exact limit of safe draught upon the artesian supply is really the crux of the problem.* Here again, however, the question is not quite definite. Suppose, for example, that the opening of fresh bores should be followed by diminutions of flow in others, there may still be increase of advantage, for the maximum benefit really occurs when the total efflux from all wells is utilized with the best economic results, *not* necessarily when it is an absolute maximum. From this it follows that every bore giving a flow in excess of

what can be well utilised, ought to be partially shut down, so as to reinforce other bores, and to conserve the supply.

2. *Danger of passing to the sub-artesian condition.*—In some artesian areas in the United States, the success of artesian irrigation and the economic value of the intense culture that followed, led to such a multiplication of bores, that the supply at last became sub-artesian in many of the bores giving previously a spendid discharge.

And here it may be pointed out that the question of whether the condition in the artesian strata is *hydraulic* or *hydrostatic*, stands out in clear relief. If hydrostatic, then the question resolves itself practically into an inquiry into two elements only, viz. :—

(1) The total intake per unit of time, say per year,

(2) The reaction of each bore on neighbouring bores.

If however, the water in the stratum is *flowing*, then the solution of the whole problem adds another element, viz.:—

(3) The disposition of bores which gives the largest, and best distributed yield.

If the rate of artesian flow is exhausting the supply faster than it is made good by the sources of supply, a diminution of flow (or pressure) will inevitably reveal the fact. The form of the *curve of diminution*, as it may be called, will give some clue to the ultimate consequences of the flow, and will have local characteristics. We shall later return to the point.

When the efflux falls to zero, the sub-artesian condition has been reached, and the water can be made available only by pumping.

3. *Economic effect thereof.*—After this condition, viz., that of ordinary wells, has been reached, though still possible to draw on the supply, the economic aspect of the question is considerably changed. It has been found from practical experience, that culture which pays when the

irrigation is gravitational, sometimes does not pay when it involves pumping. If economic developments take place on a scale justified by gravitational irrigation from artesian sources, and the condition should change, the economic disaster may of course become serious, even though there is still a sure supply. This suggests the—

4. *Necessity for scientific investigation.*—Should the artesian waters be drawn upon to such an extent as to convert the whole artesian area to the sub-artesian condition, wells originally flowing freely becoming practically useless, we are surely reverting to the original condition of aridity. Consider for a moment how this may arise.

Professor Gregory's theory as an hydraulic explanation may, we think, be dismissed, because even though gaseous pressure and thermal expansion be contributory factors, they would, if his theory were correct, also work in some measure against the hydrostatic head at the region of intake in a manner practically equivalent to raising the hydrostatic (and also hydraulic) head. And then the real question to deal with would be this, viz.:—'Is the *pressure-head* due to entrance of water in the region of intake the work of centuries, or of only a short period?' 'Is the draught on the artesian supply appreciably greater than the yearly increase?'

Let us suppose that the pressure-head, as it stands, is very great, being the work of centuries of accumulation; then that head, being the cause of the velocity of flow, will be maintained *so long as the total flow from the artesian wells is not greater than the yearly increment in the area of intake, but if the total flow exceed the intake supply we are on the way to inevitable disaster.* If it were possible to maintain Professor Gregory's view, the case would be even still more serious, but without adopting his view the matter is *sufficiently serious to call for public attention.*

We are going on, *blindly* exploiting our artesian waters, in face of the fact that a similar proceeding elsewhere has changed an artesian region to a sub-artesian, with consequent economic loss, and we are moreover enormously increasing the difficulty of obtaining a definite and decisive solution, such as shall constitute a sure guide as regards the control of the right to tap the artesian supply. We are increasing the number of bores without an adequate scientific examination of the phænomena. At the present time we are without that real guidance which would be afforded by a systematic analysis of the facts.

One naturally asks, 'of what magnitude is the question?' Is it really worth attack, or are the interests bound up therewith so small that we can take our chances of failure, through exhaustion of the artesian supply? That is the practical question which will not be settled until a mathematical hydraulician, with the necessary opportunity of inquiry, has closely examined the problem, even then it may not be easy to completely solve it.

IV.—The Scientific Basis of the Problem.

1. *Steady and turbulent flow.*—Fluids in a state of motion move in two ways, which we shall now define. Consider any appreciable mass of the fluid: if all its particles are moving in the same direction, that is *if its motion be one of translation only* the flow is said to be *steady*. If on the other hand some particles move across or contrary to the general motion of translation of the mass, the flow is said to be translational-rotational, agitated, vortical, or *turbulent*: that is to say there are rotational movements in a mass of fluid which as a whole is subject to a motion of translation. It may be noticed that when the physical conditions admit of the whole of the potential energy (existing as pressure) expending itself in the production of motion of pure translation, *the flow is a maxi-*

mum for a given fall of pressure. If the motion be turbulent, there is *less* translational flow for the given fall of pressure, for the energy is exhausted,—(*a*) partly in motion of translation, (*b*) partly in rotational motion.

2. *Flow in capillaries.*—In large tubes fluids flow steadily only with great difficulty, and for a given velocity it is practicably impossible to maintain steadiness when they are above a certain dimension, which has some relation to the *viscosity* of the fluid. The laws of steady and turbulent flow are discussed in treatises on hydrodynamics, and have been previously reviewed in this Society.[1]

In an elliptical tube, for example, the velocity of steady flow v of an incompressible fluid of viscosity η, is expressed by the equation

$$v = \frac{1}{4\eta} \cdot \frac{p}{l} \cdot \frac{a^2 b^2}{a^2 + b^2} \ldots\ldots\ldots\ldots\ldots (2)$$ [2]

in which p is the fall of pressure in the length l of the tube of semi-diameters a and b.

Should the flow be turbulent, as it would be both in underground fissures, and in the artesian bore itself, then the flow will be, writing i for p/l

$$v = k^c \frac{1}{\eta^d} i^n r^{ue} \ldots\ldots\ldots\ldots\ldots (3)$$ [3]

in which c and d, and n are functions of the *roughness* of the channel, and c depends upon its *absolute dimensions*, (n is unity for steady flow, and is probably never less than $\frac{1}{2}$). It may be noted here, that the fall of pressure in the artesian tube can be roughly calculated for any definite

[1] History, theory and determination of the viscosity of water by the efflux method, G. H. Knibbs—Journ. Royal Soc., xxix., 1895, pp. 77 - 146. Recent determinations of the viscosity of water by the efflux method, G. H. Knibbs—Journ. Royal Soc., xxx., 1896, pp. 186 - 193. Steady flow of water in uniform pipes and channels, G. H. Knibbs—Journ. Royal Soc. xxx., 1896, pp. 314 - 355.

[2] Journ. Royal Society, N.S.W., 1895, p. 112.

[3] Journ. Royal Society N.S.W., 1897, pp. 348-9, etc.

velocity, at least if the general condition of its surface is known.

3. *Conditions of flow in sand and rock.*—The experiments of Professor F. H. King[1] shewed that soils, sands, and sandstones may contain up to over 40% of water, sandstone ranging from 15 to 38%. Much less porous rocks may also contain water, for example, even marble will absorb 0·23%. The condition of movement may be aggregated under three categories:—

(1) Gravitational: (2) Capillary: (3) Thermal.

It will be well here to mention that the influence of barometric pressure is very marked in the case of *gravitational* movement of water; as in the discharge from springs, etc. This will be referred to hereinafter. Except as in so far as surface-tension interferes therewith, water will of course flow gravitationally (*i.e.* downward) in rock. *Capillary movement* will take place *in any direction*, but upward movement has been experimentally observed to shew diminution as indicated in the following table:—

Height	1 ft.	2·37 lbs.	2·05 lbs.	per square foot per 24 hours.
,,	2 ft.	2·07	1·62	
,,	3 ft.	1·23	1·00	
,,	4 ft.	0·91	0·90	

4. *Experimental investigation.*—Professor King made a great many experiments of the rate of percolation from sands of various degrees of fineness under gravitational head, of the capillary lift, and of the evaporation; these would be of some service in judging how much water, out of the total annual fall, may be assumed to contribute to the artesian supply. The fact referred to by Professor Gregory, that the lines of flow of water do not take the shortest direction, is easily understood. (See Fig. 1.)

[1] Principles and conditions of the movements of ground water—U.S. Geol. Survey Report, 1897-8, pp. 59-294.

Professor King's experiments of flow through a series of discs of wire gauge shewed some departure from the Poiseuille law expressed in equation (2), and similarly through discs of perforated brass, and through sandstone. F. H. Newell's experiments of the flow of water and of oil through rock also shew some departure. Flow through Italian marble on the other hand shewed good agreement, the porosity being no doubt very small.

Investigations have been made by Seelheim,[1] by Welitschkowsky[2] and Wollny,[3] the former shewing very good agreement with the Poiseuille law.

King experimentally examined the effect of coarseness of grain on rate of flow, the results led to a theoretical investigation by Professor C. S. Slichter, whose fine monograph on the motion of ground waters leaves little to be desired.[4]

5. *Theoretical investigation.*—If four spheres be placed in contact in different ways on a plane, the angles between the lines joining the centres will range between 60°, 120°; to 90°, 90°. The small angle may be called θ, see Figs. 2 and 3, the former denoting the minimum interstitial area, the latter the maximum, and the area being

Fig. 2. Sum of two shaded areas $= r^2\,(2\sqrt{3} - \pi) = 0{\cdot}32251\ r^2$

Fig. 3. Shaded area $= r^2\,(4 - \pi) = 0{\cdot}85841\ r^2$

A little consideration will shew that whether spheres are packed like Fig. 2 or Fig. 3, another sphere being on A in either, the result is absolutely the same: the figures represent two views of the closest system of packing.

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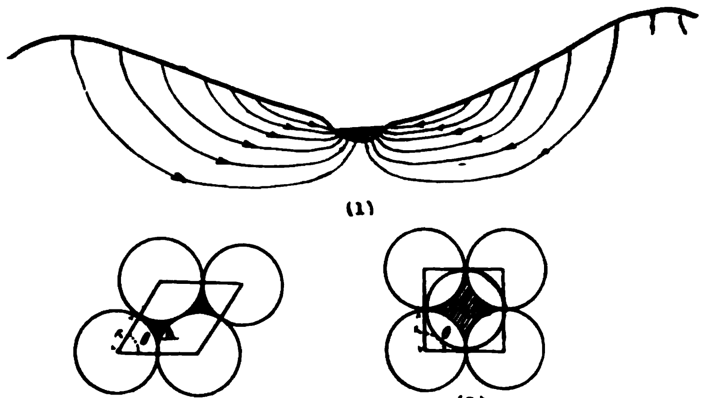
[1] Methoden zur Bestimmung der Durchlässigkeit des Bodens, Zeit. f. analyt. Chem. XIX., p. 387.

[2] Archiv. f. Hygiene, II., 499 – 512, 1884.

[3] Forschungen auf dem Gebiete der Agricultur-Physik. XIV., pp. 1 – 28, 1891.

[4] Theoretical investigation of the motion of ground waters—U. S. Geolog. Survey, Report 1897-8, pp. 295 – 384.

When a fifth sphere is placed on the four in Fig. 3, it will be seen that the interstitial volume is triangular in shape as in Fig. 2.



(1)

(2) (3)

Slichter shews that the porosity, that is the *ratio of void to total volume occupied*, viz. m to 1 is given by the expression,

$$m = 1 - \frac{\pi}{6\,(1-\cos\theta)\sqrt{1+2\cos\theta}} \quad \ldots\ldots\ldots\ldots(4)$$

from which θ may be found by solving the cubic equation—

$$2\cos^3\theta - 3\cos^2\theta + 1 - \frac{\pi}{36\,(1-m)^2} = 0 \ldots\ldots\ldots\ldots(5)$$

and that the curved length l of a triangular pore is expressed by

$$\frac{l}{h} = \frac{(1+\cos\theta)}{\sin\theta\sqrt{1+2\cos\theta}}\,(1{\cdot}195 - 0{\cdot}39\ \theta/\pi) \ldots\ldots\ldots(6)$$

in which h is the depth of the packed spheres. It is easily seen that the most *open* arrangement of spheres, viz. that when their centres are the points of cubes, gives voids the volume of which is $r^3(8-4\pi/3)$; while when the closest arrangement is followed, viz. when the centres are the points of a regular rhombohedron (60°, 120°) the void-volume is $r^3(6-4\pi/3)$. Hence the porosity m in one case is $1-\pi/6$

and in the other $1-\pi/3\sqrt{2}$, that is to say, 47·6401% and 25·9520% respectively. It would appear from this that 48% is about the maximum porosity, and since the interstices can be filled with still smaller grains, that sand may also be *less* porous than 25%.

Professor Slichter solves for flow in triangular and other sections. This part of the work leaves something to be desired in the shape of rigour, but no doubt the solution is a highly approximate one. What Slichter has shewn to be very important is that the *porosity* (with which θ varies) *has great influence on the flow.* Any formula that does not take it into account is quite *inadequate.*

6. *The lines of flow.*—In applying Poiseuille's,[1] and Darcy's[2] law, viz.:—

$$v = k\ p/l \ldots\ldots\ldots\ldots\ldots (7)$$

it is shewn that the constant k depends upon three things, viz.:—

(*a*) The *viscosity* of the liquid, *i.e.* upon *temperature.*

(*b*) The *size of the grains* of soil.

(*c*) The *porosity* or ratio of the voids to the total volume.

Since the flow is in an approximately horizontal stratum of porous rock lying between relatively impermeable strata, one may, in determining the lines of flow under given conditions, assume it to take place in two dimensions. The equations of motion are then simply

$$u = dx/dt = k\ \partial p/\partial x \ldots\ldots\ldots\ldots (8)$$

$$v = dy/dt = k\ \partial p/\partial y \ldots\ldots\ldots\ldots (9)$$

that for determining p being

$$\frac{\partial^2 p}{\partial x^2} + \frac{\partial^2 p}{\partial y^2} = 0 \ldots\ldots\ldots\ldots (10)$$

an equation which remains true even if the velocity vary in such a form, as say $v = kp + c$, where c is a constant.

---

[1] Poiseuille—Recherches sur le mouvement des liquides dans les tubes de très petite diametres.—Mém. des sav. étrang. Acad. Sc. 1842, IX., p. 433.

[2] H. Darcy—Les fontaines publiques de la ville de Dijon, Paris, 1856.

We shall omit all reference to the solution of Laplace's equation, and the application of the method of conjugate functions or conformal transformation,[1] remarking simply that in many cases one must be content to assign a value to the potential function and then determine the boundary conditions which will render the proposed function a true solution.

The following are a few cases of interest.

In Fig. 5, suppose A to be a point ('source') where a liquid is supplied to a stratum of indefinite area, and B a point ('sink') out of which it flows, then the flow will take place along the system of *dipolar circles*. These theoretical results can easily be demonstrated experimentally.[2]

In Fig. 6, suppose A and A′ to be both sinks (say two artesian wells) then the flow will be along the lines in the direction marked by the arrow heads.

Fig. 7 illustrates the case of deflection of flow, initially in the direction D (see arrow), by the 'sink' or well W. The line BB is the dividing line on the left hand side, the flow going toward the well, on the right-hand side along the stratum.

Imagine a stratum initially without flow in any direction, penetrated by two 'sinks' or wells, the efflux volume being twice as much in (2) as (1), see Fig. 8. The flow will then take place as indicated.

Again if two equal 'sinks' or wells be put down into a stratum with an initial flow in the direction D, the flow towards the wells will be as shewn in Fig. 9.

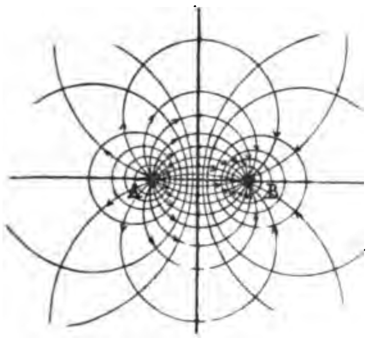
These and similar cases have been solved,[3] and throw light on the motion of water near wells, and on the reac-

[1] Einführung in die Theorie der isogonalen Verwandschaften.—Gustav Holzmüller, Leipzig, 1882.

[2] See Engineering, April 8, 15, 1898, pp. 444 – 477, etc.

[3] By Professor Slichter and others.

tion between one well and another. If the stratum is non-uniform in thickness, porosity etc., the lines of flow will not be regular but will be deflected.



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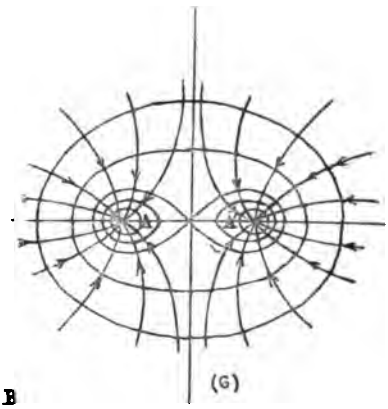

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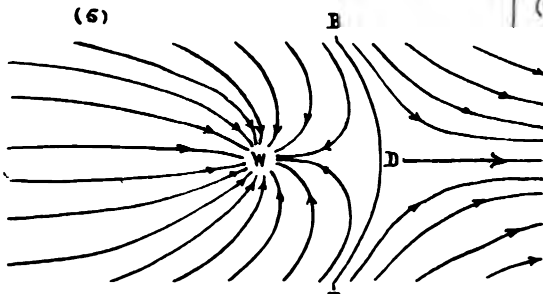

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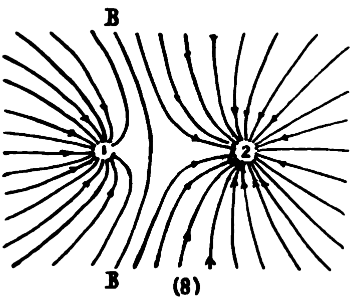

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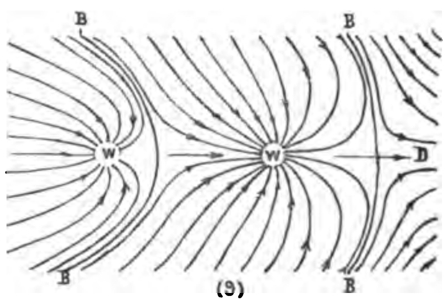
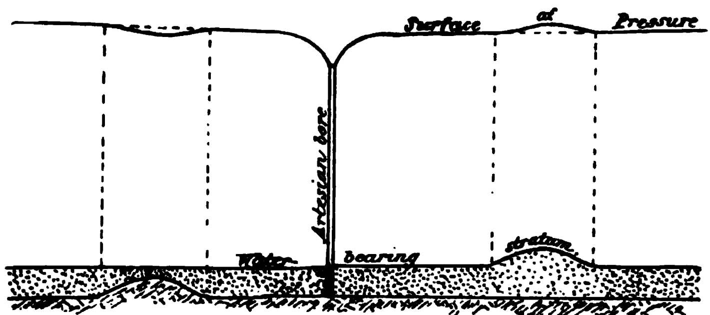


(9)

7. *The curve of pressure.*—As the flow in any stratum increases its velocity, so the pressure falls. Imagine a

number of minute tubes penetrating the artesian stratum, and distributed around the artesian well so as to form manometers, shewing the pressure heights. Then the surface defined by these heights, viz., the heights to which the water would rise in these tubes, would form the *surface of pressure*, and level contours would thereupon be *curves of equal pressure*. The system of curved lines orthogonally intersecting these would denote the lines of flow. (See Fig. 4.)



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Deg. C.	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°[1]
Fluidity	1·00	1·36	1·77	2·22	2·72	3·23	3·77	4·34	4·92	5·52	6·13

In turbulent flow the viscosity has relatively very small influence, so that *in the stratum* the temperature effect is *large*, but in the pipe it is very small.

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[2] Nature, Vol. XXVIII., p. 367.

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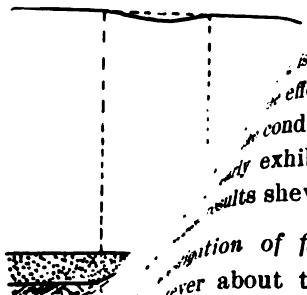

so that the actual phænomenon,
is not easy of exact analysis, inas-
effect of low pressure must be ascer-
conditions are definite, the barometric
...rly exhibited, and there are a number of
...sults shewing this to be the case.

8. (... *...ation* of *fluctuation of flow.*—There is no
It i ... *...ever* about the fact that the movement of
o ... *...high* and low pressure across the artesian area,
r ... *variation* of flow. A perfect determination of
...in which these act will not perhaps be easy, but
...ent data will certainly make it possible to deduce the
...theory of variation of efflux or pressure. Some observ-
...ations already exist, but for subartesian wells only so far
as I am aware. It is very easy to get records for any type
of well, flowing or otherwise, by connecting one end of a small pipe with the artesian bore, some distance downward from the top of the bore and the other end with a manometer, or better still a self-registering-pressure gauge. A record of pressure variation can in this way be obtained. It is very desirable of course that these should be supplemented with measurements of the absolute volume of flow. Besides large variations of pressure, there are also smaller oscillations of short period, the cause of which is not yet explained.

actual problem.—In its absolute
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way of narrowing down our deductions to
.estions,

what extent may we push exploitation?

, Are we exhausting our artesian supply, or is the loss being made good?

(c) What are the distance and other conditions which should govern the frequency of bores?

V.—Conclusion.

1. *How and when investigation should be made.*—The difficulty of any real attack on the problem perhaps now more fully appears; and it remains but to add a few words on the practical drift of the matter. And first we may ask, 'How and when should the investigation be made?'

First as to the *how* of the examination. Primarily it may be said that the hydraulic question is quite *outside* the range of ordinary professional engineering, for it presents mathematical difficulties of a very special character. Secondly, to reach an adequate solution, the characteristics of the increase of pressure on diminishing the flow, and of the reaction on adjacent bores must be ascertained, therefore in the investigation every facility must be given by those in charge of the bores or by those to whom they belong. The conditions of satisfactory inquiry may consequently be summed up substantially as follows:—

(*a*) Special command of hydrokinetics.

(b) Comprehensive and deliberate investigation.

(c) Opportunity to make required tests at the various bores.

(d) Insistence in future that complete and accurate records of all strata pierced shall be kept.

(e) Insistence on the making of suitable flow and pressure observations at new bores.

(f) Utilisation of all other sources of knowledge, *i.e.*, geology, chemistry, biology, etc.

Thirdly, '*When* should the investigation be made?' The observation of the phænomena of varying pressure and efflux, should undoubtedly have commenced when the first bore was opened, and should have been going on ever since. As previously stated, the difficulty has been *seriously increased* by neglect to do this, and the longer the lapse of time before we start, the greater the region of uncertainty in the resulting information. For in rightly deciding the most probable initial pressures and other conditions in the artesian stratum, lies the true solution of the problem. The failure of our artesian supplies would be a great calamity, and too big a price to pay for any want of foresight.

2. *Necessity for legislative control of frequency of bores.*—A rule for determining how far it is wise to allow the tapping of the artesian sources, must be dependent upon the results of the investigation indicated. There is no other exact way of deciding which is not wise *after* the event. The solution must not be through disaster. The interference of one bore with another, and the *possibility of general failure*, all go to shew how careful should be the control of the whole matter. Boring is a matter of some expense, and the best control in the common interest is the *crux* of the solution, and asks urgently for that

thorough investigation which alone is a true basis for practical guidance.

3. *The future of artesian exploitation.*—How to exploit our artesian waters so as to secure the *maximum economic advantage*, that is the practical question which is presenting itself for settlement, and the future of our artesian system largely depends thereupon. It may be that the area of intake, and the rainfall thereon, is adequate for any number of bores likely to be made. On the other hand we may be recklessly playing with an economic capital which it has taken centuries to accumulate. Though it is not possible for us to agree with Professor Gregory's conception of the hydraulic aspects of the problem, this at least may be fairly inferred from what he says, viz., that the supply may be exhausted, and that the great pressure occasionally manifested is, after all, no sufficient ground for believing the artesian supply to be practically inexhaustible.

Without in any way being alarmist, it must be admitted that we know altogether too little about the physical and hydraulic conditions of a problem upon which economic development in our arid interior is greatly dependent. We are smilingly drawing on our capital: is Nature not only honouring the draft but keeping our credit balance in her bank everlastingly good? That is just what we *want* to know and do *not* know.

THE QUESTION OF THE OCCURRENCE OF LIVING ORGANISMS IN THE ARTESIAN WATERS.

By Professor W. A. HASWELL, M.A., D.Sc., F.R.S.,

[Read before the Engineering Section of the Royal Society of N. S. Wales, July 20, 1903.]

THE occurrence of living organisms in the artesian waters of Australia is, when the subject is regarded from an *a priori* standpoint, a matter of high probability. Numerous organisms, many of them by no means of the lowest grade, have been found to flourish in water of springs the temperature of which is much higher than that of the water issuing from most of the artesian bores. In hot springs in Italy it has been found that life of various kinds is fairly abundant, even when the temperature of the water approaches 40° C.[1] Nor is there anything in the nature or amount of the mineral salts in solution in the water that would interfere with such a development. Moreover, in Texas, and in Algeria[2] a variety of animal organisms—molluscs, crustaceans, fishes, and amphibians—have actually been obtained in the water issuing from bores tapping artesian basins.

The animals that have been found hitherto in artesian waters have in a good many cases proved distinct from any of the forms occurring in the surface waters; so that something more is involved than the mere chance passage of a larval fish or river-crab through crevices into the subterranean reservoirs of the artesian basin: there must be a

[1] Issel—Atti Accad. Sci. Torino, xxxv., 1900, and xxxvi., 1901, as quoted in Année Biologique, v.

[2] Les Forages Artésiens de la Province de Constantine (Algérie). Résumé des travaux exécutés de 1856 à 1889. Par M. Jus. Constantine, 1890. I am indebted to the courtesy of Mr. J. W. Boultbee for the opportunity of consulting this report.

fauna existing there permanently: a fauna doubtless introduced originally in a fortuitous manner from the surface waters; but now established permanently underground, a fauna differing in a sensible degree from that which now inhabits the surface waters. It is this last consideration which lends its main interest to an investigation of this subterranean aquatic fauna in Australia. While the freshwater animals inhabiting the rivers and lakes of the surface have been subject at intervals to wholesale destruction owing to the complete desiccation of rivers and lakes in time of drought, the subterranean fauna may be supposed to have been protected from this destructive influence; and it is not too much to hope that forms no longer represented in the surface fauna may survive in the artesian underground reservoirs.

When I first began some inquiries into this subject a few years ago, I found that there were rumours in abundance of animals—fishes for the most part—having been discharged from the bores; but there was apparently an absence of trustworthy evidence that they had actually passed out in the artesian water. It is well known that when new dams are formed, even at a considerable distance from other water, a population of crayfishes, water-snails, and mussels, water-beetles and other aquatic insects, and frogs and fishes, appears in it with what seems remarkable rapidity: and such a development, in the case of the new dams and tanks filled with the artesian water, might lead to the erroneous conclusion that the animals in question had actually issued forth in the stream from the subterranean reservoirs. To prove that any animal is in reality a member of the artesian fauna, it must not be merely picked up in the neighbourhood of the bore, but must be actually caught in the act of issuing forth from it. For the purpose of collecting such artesian animals

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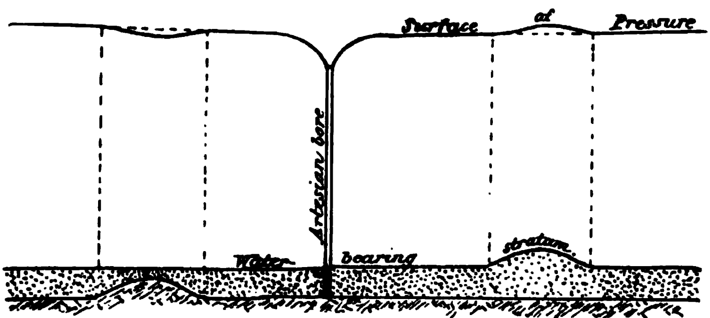

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[1] G. H. Knibbs—Journ. Royal Soc., xxvi., pp. 318-319, 1897.
[2] Nature, Vol. xxviii., p. 367.

perhaps twice this. If such a deduction be correct, it is evident that one might expect to find the pressure or efflux in any artesian well correspondingly variable. Again, it may be observed that *fall* of barometric pressure will destroy the equilibrium of the contained air in rocks and soil and act virtually as an increase of hydrostatic pressure. Thus both *increase* and *diminution* of pressure, tend to produce identical results. But in the one case, viz., the former, the action is practically instantaneous, in the other it is decidedly otherwise; so that the actual phænomenon, the resultant of both, is not easy of exact analysis, inasmuch as the lag in the effect of low pressure must be ascertained. Where the conditions are definite, the barometric influence is clearly exhibited, and there are a number of experimental results shewing this to be the case.

11. *Investigation of fluctuation of flow.*—There is no doubt whatever about the fact that the movement of centres of high and low pressure across the artesian area, cause a variation of flow. A perfect determination of the way in which these act will not perhaps be easy, but sufficient data will certainly make it possible to deduce the real theory of variation of efflux or pressure. Some observations already exist, but for subartesian wells only so far as I am aware. It is very easy to get records for any type of well, flowing or otherwise, by connecting one end of a small pipe with the artesian bore, some distance downward from the top of the bore and the other end with a manometer, or better still a self-registering-pressure gauge. A record of pressure variation can in this way be obtained. It is very desirable of course that these should be supplemented with measurements of the absolute volume of flow. Besides large variations of pressure, there are also smaller oscillations of short period, the cause of which is not yet explained.

12. *Real form of the actual problem.*—In its absolute form, the problem is insoluble, that is to say we shall probably never know with exactitude the condition of the artesian strata. But it is possible to construct for each well, what may be called its *theoretical equivalent;* and by careful investigation of the evidence, to constitute a *representative stratum of similar behaviour.* If that be well done, it will be a *true* guide, and it will reveal what is possible in the way of narrowing down our deductions to the great questions,

(*a*) To what extent may we push exploitation?

(*b*) Are we exhausting our artesian supply, or is the loss being made good?

(*c*) What are the distance and other conditions which should govern the frequency of bores?

V.—Conclusion.

1. *How and when investigation should be made.*—The difficulty of any real attack on the problem perhaps now more fully appears; and it remains but to add a few words on the practical drift of the matter. And first we may ask, 'How and when should the investigation be made?'

First as to the *how* of the examination. Primarily it may be said that the hydraulic question is quite *outside* the range of ordinary professional engineering, for it presents mathematical difficulties of a very special character. Secondly, to reach an adequate solution, the characteristics of the increase of pressure on diminishing the flow, and of the reaction on adjacent bores must be ascertained, therefore in the investigation every facility must be given by those in charge of the bores or by those to whom they belong. The conditions of satisfactory inquiry may consequently be summed up substantially as follows:—

(*a*) Special command of hydrokinetics.

Humus.—In the first place is to be remarked the deficient amount of humus matter. The absence of moisture is also equally noticeable, but although the comparative figures given probably represent very nearly the proportionate amounts as compared with other soils, the individual figures are not altogether trustworthy, since the amount found in the soil on arrival in the laboratory is by no means always an indication of its condition *in situ*. The soils were, however, invariably dry, and the average probably very nearly represents the average contents of the soils if determined on the spot. The humus deficiency is, however, a definite one, and has to be seriously taken into account in any scheme for the improvement of these soils. It is due, of course, to the absence of moisture and the burning action of the sun. Moisture is necessary for the decay of vegetable matter. This defect will be remedied by irrigation; firstly, by deposition of the silt which is carried in suspension by even the clearest river water, and which contains a certain amount of organic matter; and, secondly, by supplying the necessary moisture to enable the decay of vegetable matter to proceed.

Capacity for Water.—The next point of importance is the capacity of these soils for water, that is to say, their water-retaining power. These figures represent the percentage amount of water which the soil is capable of holding. This property depends partly upon the amount of humus present, which has a very high capacity for holding water, and partly upon the mechanical condition of the soil, the relative proportions of coarse and fine sand and clay. It is noticeable that the light sandy loams, those soils in which the amount of clay does not exceed 12 or 15 per cent., have a very low retentive power for water. The average of these soils is, however, about the same as it is for similar light sandy loams in other parts of the State. This is true, also, of the soils in which the clay content is higher, in the

loams and heavy loams. With the increase in decayed vegetable matter, which, as we have seen, will be one of the results of irrigation, this retentive power for water will be considerably improved. This is exemplified in the case of the soils from the Richmond River and other places, and is especially noticeable in the laterite soils from Malaya, where the increased humus content has increased the water-holding capacity of the soil enormously, although the proportions of sand and clay are, on the average, the same as in our Western soils. This characteristic of the soil to absorb and to retain moisture is one of the very greatest importance in determining their fertility, and although the average of the soils examined from the semi-arid regions is lower in this regard than the average of soils from other parts of the State, it must be borne in mind that these soils are for the most part sandy soils, and only fairly comparable with similar sandy soils from other parts.

The average water-holding capacity of the loams and heavy loams will be found to be quite as high as that of the same class of soils from other places. It is, I think, a matter of congratulation that we are able to assure ourselves that, in this important particular, the soils in our drier districts are in no way inferior to those of more favoured regions.

Mineral Plant-food.—A second very striking peculiarity in these soils is the large amount of mineral plant-food present. It will be seen, on comparing them with the County of Cumberland soils, for example, that they contain about three times the amounts of lime and potash, and twice as much phosphoric acid. This is, of course, largely to be attributed to the absence of water, which, in more humid regions, carries away a considerable proportion of saline matter into the sub-soil. To show that these peculiarities are not abnormal, and that they correspond with what has been observed elsewhere, I quote some

figures given by F. H. King, Professor of Agricultural Physics at the University of Wisconsin, in his book on "The Soil," contrasting the chemical nature of arid and humid soils. The figures are taken from analyses of Hilgard:—

III.—Comparison of Soils from Humid and Arid Regions of the United States. (From F. H. King, "The Soil.")

	Humus.	Nitrogen.	Lime.	Potash.	Phosphoric Acid.
Soils from humid regions...	3·04	·13	·11	·22	·11
Soils from arid regions	0·75	·10	1·36	·73	·12

In these figures it will be seen that the difference between the amounts of mineral plant-food are even more strongly marked than is the case with the figures dealing with our own soils. The explanation given by Professor King is the same as I have suggested, namely, "that sufficient water falls for the decomposition of the rock, and the formation of alkalies and of zeolitic mineral" (zeolites are soluble in hydrochloric acid), "but not enough to remove these when formed, as is the case in arid regions." The fact that these soils are richer in mineral plant-food is one of considerable importance in relation to their fertility, though it must be remembered that richness in plant-food is only one of the elements of fertility, and that this property alone is not sufficient to render a soil fertile.

Humus in American Soils.—A much more striking difference in our soils and in those of similar soils in the States, as examined by Hilgard, is the relatively large amount of organic matter as compared with the "humus" shown in Hilgard's analyses. It must be explained that the organic or volatile matter in our analyses is not strictly humus only, but includes unchanged vegetable matter, small root-fibres, and so forth, which are sometimes present in these soils in considerable quantities. It also includes water of combination and carbonic acid. The true humus—that is, the decayed vegetable matter—is certainly much smaller in

amount, and the very striking peculiarity has been pointed out by Hilgard that the humus in arid regions is very much richer in nitrogen than is the case with the humus in moist regions. So much is this the case that the nitrogen in the humus in arid regions rises as high as 15 per cent., or about three times the amount present in the humus of humid regions, which is about 5 per cent.

Powdery condition of the soil when dry.—A third striking characteristic of these soils, and one not shown in the tables, is their peculiar powdery condition when dry. Everybody who has been in the districts referred to is aware that the surface soil over large areas is carried away by the wind in the form of a fine dust, which is deposited against outstanding obstacles, or, if unobstructed, is carried enormous distances, to be ultimately deposited when the wind subsides, or carried down in the form of mud by a shower of rain. This phenomenon is noticeable in all arid regions, and Hilgard attributes it to the larger content of lime which these soils contain. It is well known that the addition of lime to clay renders the clay pulverulent and incoherent on drying. There are, however, reasons which make it difficult to accept this as a complete explanation of the cause of the incoherent nature of our soils. In the first place the quantity of lime, though larger than in the case of the soils from the more humid parts of the State, is not by any means excessive, and it is only exceptionally that they contain as much as is found in the average of the soils examined by Hilgard. In connection with this matter, Mr. Cohen has made some experiments in our laboratory in regard to the behaviour on drying of clay soils mixed with different quantities of lime. He finds that a clay soil containing ·53 per cent. lime (an amount above the average in our soils) when moistened and subsequently dried, became quite hard—as hard as clay which contained no lime—and

that the addition of 1·5 per cent., making 2 per cent. in all (an amount which is above the average of the soils quoted by Hilgard), had very little effect indeed upon the texture of the soil when dried. It required the addition of at least 3 per cent. (about 15 tons per acre 1 foot deep) to reduce the soil when dry to the crumbly condition characteristic of the soils of this region. It would seem, therefore, that some other cause, probably the absence of humus, operates in addition to bring about this state of things. This is a subject that will repay further investigation.

Nitrification.—The nitrifying power of the soil is one of the most, if not the most, important index of its fertility, since not only does a vigorous nitrifying power ensure to the plant sufficient nitrates, which are essential to its proper development, but the conditions which promote nitrification, namely, aeration, moisture, and warmth, are exactly those which make for fertility. In this connection I will submit what Mr. Helms, who has given this subject his special attention, has to say on the matter. Nitrifying organisms appear to be present in all the soils examined, with the exception of swamp-soils on which water has lain for some period, and of extremely sandy soils. Sourness of the soil is detrimental to their growth, and, what is of special interest to our purpose, dryness of the soil affects the vitality of these organisms very strongly. In dry soils their vitality is considerably affected, and their development, when placed under favourable conditions, is very slow. When they have once started to develop, however, their further growth proceeds fairly rapidly. It would appear that dry conditions, though they do not actually destroy the nitrifying organisms, reduce them to a dormant condition. The beneficial effects of irrigation were strongly marked in some samples from rice-fields near Bangkok. These were received in small hermetically-sealed

tins, and were quite moist on arrival. The nitrifying organism was present in large quantity, and its development was extraordinarily rapid. Excessive heat has, of course, also a detrimental effect upon these organisms, and both excessive heat and want of moisture are conditions which prevail in the class of soil under discussion. Hence these soils are characterised by the slowness with which the nitrifying process takes place, but although the vitality of these organisms is impaired, or their condition modified to the extent that their development is exceedingly slow, in no case are they absent, and, when once they commence to develop, the development continues at a normally rapid rate. The conditions which favour their development within the soil, namely, aeration, moisture, and equable temperature, are conditions which will result from properly conducted irrigation. Similarly, the nitrogen-assimilating organisms which occur in the root-nodules of certain plants depend, of course, upon the vigorous growth of these plants, and, without irrigation, it appears hopeless to attempt to grow leguminous plants in these districts.

Quantity of water required by different Crops.—I do not propose to go deeply into this subject. A large number of careful experiments have been, and are being, conducted, more particularly in Germany and America, to establish the requirements of the different crops with regard to water. All growing plants and trees are continually pumping up water from the soil and evaporating it through their leaves. The surface of an area of cultivated land exhales enormous quantities of water as vapour into the air. This free passage of water through the plant appears to be necessary for its growth, and though cases are known in which plants have been able to adapt themselves to circumstances and to grow in a very limited supply of water, still for the normal production of crops it may be assumed that sufficient water for this purpose is essential.

Food is dissolved in Water.—The food received by the plant is nearly all absorbed in solution by means of the root-hairs, and there must be sufficient water to dissolve a part of the mineral matter of the soil. It is generally conceded that an annual rainfall of 18 inches or over is necessary for the growth of wheat. In our case, unfortunately, it usually happens that in the area of diminished rainfall the greater part of the rain falls in the first three or four months of the year at a time when it is of no benefit to the crop. If the rain fell in the spring and summer months, a much smaller amount would be sufficient.

Prevention of Loss of Water from Soil.—I am of the opinion that a good deal can be done even in the absence of irrigation to ameliorate the conditions of farming. There are large areas in the State where it is out of the question to establish irrigation works—at all events, for many years to come. It then becomes a question of conserving within the soil the moisture present in the soil, and though this is hardly an aspect of the matter that is of much interest to the engineer, it is, nevertheless, a question of very great importance how to counteract the continual loss of water which evaporates from the leaves of the plants and from the surface of the soil. I shall, however, not discuss the matter at any length, but shall enumerate a few of the operations which will be found of benefit in conserving water in this way. The planting of belts of trees to break the force of the winds is a very important operation, since evaporation from both leaves and soil is greatly accelerated by the passage of wind over the land. Mulching of the surface soil, liming, thorough tillage, and a proper system of drainage are all operations which result in the production of a fine spongy texture in the soil, which increases its water-holding capacity and reduces the amount of surface evaporation.

Fertility.—To sum up the conditions which determine fertility they are :—

Sufficiency of plant-food, of humus, and of water.

A proper proportion between the amounts of sand and clay.

An open texture which allows of free passage of air and water, and is sufficiently close to allow of capillary action.

On the texture depends the power of the soil for retaining water, its nitrifying power to a large extent, the solvent power of the soil-water, and the maintenance of an equable temperature. All these conditions are threatened if water is absent, and all are improved under irrigation if properly carried out.

Irrigation Fertilises.—Irrigation is of value also on account of its direct fertilising effect, since all water contains more or less saline matter in solution, which is retained by the soil, and acts as plant-food.

Injurious Substances.—There are, however, certain waters which contain substances which in quantity are injurious to plant-life, and such waters must be employed with caution. The most commonly occurring of these substances, as far as we are concerned, are common salt and carbonate of soda. These salts have an injurious effect both upon the plant and upon the soil.

We have found by direct experiments in pots that the growth of wheat is affected by quantities as low as ·05% to ·15% of common salt, whilst ·2% prevented germination.[1]

Carbonate of soda (alkali) affects the growth of the plant when present to the extent of ·1%; ·3% prevents germination and growth. The effect of alkali upon the soil has been brought under your notice already by Mr. Boultbee, in his quotations from Prof. Hilgard, who is our principal authority

[1] F. B. Guthrie and R. Helms—Journ. Roy. Soc. N.S.W., xxxvi., p. 191.

on the subject of alkaline soils. I may add our own observations on soils which had become charged with alkali from continuous flooding without efficient drainage or correctives. Such soils are very rich in mineral plant-food, notably in potash, but deficient in humus and in nitrogenous matter. Their capacity for water is reduced. The soils become hard, so hard that some of the samples had to be taken by means of a crowbar. The tendency of continued irrigation with alkaline water is to destroy the organic matter, the soil becoming cemented together so as to render tillage operations difficult and finally impossible.

A knowledge of the behaviour of these salts is of importance to us in view of the fact that a large proportion of our artesian water is charged with one or other of them, for instance—

Cuttaburra Bore ...	350	grains	NaCl	per gallon.
Opera Bore	278	,,	,,	,,
Baneangle Bore... ...	172	,,	,,	,,
Sandy Creek Bore ...	108	,,	,,	,,
Clifton Bore	98	,,	Na_2CO_3	,,
Osaca	56	,,	,,	,,

The above figures are taken from analyses published by J. C. H. Mingaye.

There are many others containing over 30 grains per gallon of carbonate of soda. It is quite clear that the continued use of such water, if allowed to lie on the land, would in course of time prove detrimental, and I have examined soils where the land has been thus flooded without drainage, or any attempt to correct the alkali present, which have shown as much as ·9% alkali, and exhibit all the peculiarities described by American writers as characterising their alkali deserts.

Speaking generally, if this kind of water has to be used, it should be employed with judgment, and care should be

taken in the selection of such crops as are most capable of resisting the action of these salts. This, combined with a system of drainage wherever practicable, good tillage, and the use in some cases of substances known to correct the alkali, such as gypsum on the soil or in the water, will, I think, enable us to utilise such water with advantage on these soils.

I have endeavoured to lay before you the chief points which are to be considered in any scheme by which it is proposed to render farming profitable on this class of soil by the aid of irrigation, whether with river or with artesian water, and have directed your attention to the dangers which are to be avoided. With a knowledge of these dangers, and of the means for combating them, there should in my opinion, be no difficulty in the application of irrigation, but if the water is applied without some appreciation of the problems of soil chemistry and soil physics, I am convinced that much disappointment and much actual failure will be experienced.

From the chemical point of view discussed in this paper, there is no room for doubt that the soils of our arid districts are admirably adapted for cultivation by means of irrigation, abundance of water properly applied, being the only thing necessary to render them extraordinarily fertile, and it is in the establishment of co-operative irrigation colonies, such as exist in similar arid districts in other parts of the world, notably in the Western States of America, that we may look forward confidently to an expansion of our agricultural resources hitherto undreamed of.

A REVIEW OF WATER CONSERVATION IN NEW SOUTH WALES.

By L. A. B. WADE, Assoc. M. Inst. C.E.

[*Read before the Engineering Section of the Royal Society of N. S. Wales, July 20, 1903.*]

A COMPARISON of the rainfall of Australia with that of other continents, shews it to be the most arid portion of the globe. The map of Australia at the end of this paper, shews the areas over which the annual average is less than 10 inches, less than 20 inches, and over 20 inches. Country with less than 20 inches of rainfall is considered as "arid" by the hydrographers of the United States Geological Survey, and taking the same classification, it follows that of the three million square miles included in Australia, two millions are arid. The State of New South Wales includes a part of the arid area, and the development of this area for agricultural or pastoral purposes must depend on the utilization of the water of the Murray River watershed, and the artesian water where available. The areas of the watershed and the artesian basin are both shewn on the map. Before any large and comprehensive schemes for appropriating these supplies can be carried out, it is evidently necessary that the physiographical conditions of the country should be studied, and this requires that observations should be made and recorded during considerable periods of time. It will be interesting to briefly review the progress made by the pioneer officials who cleared the way for the constructing engineers of the present time.

The first work for conserving water appears to have been done in 1869 when several small tanks were excavated in the drier localities. The first artesian bore was driven in

1884. Such works should naturally have been carried out by the Department of Public Works, but in those days the questions of occupancy and revenue were considered paramount, and they were administered by the Department of Lands. Later on they were transferred to the Department of Mines, and after that to the Chief Inspector of Stock. It appears that the various Governments treated the subject with small respect, and it is clear that it was not considered important, although all the travelling stock routes were waiting to be opened up.

In 1884 a prolonged drought had so intensified the public clamour that the Government appointed a Royal Commission to report on Water Conservation under the presidency of Mr. (now Sir) William Lyne. This Commission presented three reports, of which the first, giving an abstract of the information available at that time, is still useful for reference. The principal advance made was a recommendation that the complicated tangle of riparian rights which had been imported with the English Common Law should be finally disposed of by proper legislation. It may be remarked that the recommendation was ignored for ten years. The commission expired in 1887 and its officers were transferred to the department of Mines.

During the next few years the officers continued the work begun by the commission, making surveys of various sections of the country, procuring gaugings of the rivers, and drafting the information. There seems to have been a perennial difficulty in securing funds for such purposes, and the small sub-branch was subjected to several retrenchments, and transferred from one Minister to another in a manner ill calculated to promote its progress. However, since that date, the whole subject has become of more importance, and at the present time all works of conservation are dealt with in the Department of Public Works, as, no doubt, they should be.

Four acts of Parliament have, up to the present time, been passed to deal with Water Conservation. As the whole of the operations of the department are carried on under these acts, I will briefly describe them now :—

The Public Watering Places Act was passed in 1884, and was designed to promote the policy of providing water supplies to stock when travelling on dry routes. At that time, the more remote districts of the colony were only accessible in wet seasons unless some water supplies were created along the roads. The act provides for the establishment of reserves and public watering places, and gives authority for the construction of the works necessary to yield the supply. When the works are completed they are placed in the hands of a caretaker, or leased. Consumers are charged for water at the following rates :—horses, cattle, or camels, one penny per head, sheep one shilling per hundred, goats and pigs, one farthing per head.

At the present time there are 315 tanks, dams, wells, or springs, administered under the act. The tanks are usually excavated to a depth of 15 or 20 feet, and their capacities range up to five million gallons each. In addition, there are 63 of the public watering places supplied by means of artesian bores. The act may be said to have served the purposes for which it was intended, but the revenue hitherto derived from the rates has not been sufficient to recoup the working expenses. It would be impracticable to arrange a reasonable system of rating which would entirely cover the expenditure, yet the direct benefit to stockowners, and consequently the indirect benefit to the country, is very great. Public watering places must therefore be classed with those other works, such as ferries, for example, which only make an indirect return to the State.

The Artesian Wells Act was passed in 1897 to enable groups of settlers to have a bore driven by the State on

their undertaking to pay an annual rate not exceeding 6% of the cost of the work. An artesian bore in this State is generally too expensive an enterprise for a small selector, as the average depth required to get the supply is over 1,000 feet. At the same time a successful bore will deliver more water than several selectors can properly utilize. The Crown, therefore, sinks the bore, taking all the risk of finding the artesian water, lines it with metal casing, and constructs the drains to each holding. The local Land Board then assesses the rate payable by each landowner to the Crown. As the progress of such schemes could be blocked by a single litigious settler, the act provides that the work can be carried out if the holders of three-fourths of the area agree to the proposal; this is a most important feature of the act. There are now 17 of these bores completed, and 5 others are in progress. After the stock have been supplied, there is sometimes a surplus of water which can be used for watering a small garden, and it is encouraging to note that some progress has already been made in this way.

The Water Rights Act, passed in 1895 is the most important of all. Previous to its passage, the landowners on either bank of a stream practically owned the flow of the water. This is the usage under the Common Law of England, but the natural conditions there, are of course, quite different to the conditions of the arid country here. Under the act, all the flowing water of this State became vested in the Crown. It may be remarked that similar legislation was necessary in the United States to promote the settlement of the arid areas there. The main idea is that water should be looked upon as the essential adjunct to the land. The act provides that the State shall be henceforth considered the chief conservator of water, and its officers are authorised to take any measures necessary for this purpose. Private individuals are entitled to take

water from a river for domestic purposes, or for watering stock, or for the irrigation of a garden of less than 5 acres attached to a dwelling. For all other purposes a license must be obtained from the Crown. These licenses are issued for a period not exceeding 10 years, and the holder has exclusive use of the work even against the Crown. Licensed works are generally dams across small streams for holding up a supply, cuttings through river banks for the abstraction of flood-waters, or pumping plants. Up to the present time nearly a thousand of these licenses have been granted, and the number is likely to largely increase. The act also provides various penalties for polluting or wasting any water supply, and one section was designed to make provision for carrying out public works of conservation or drainage, but this part of the act has been now superseded by:—

The Water and Drainage Act, passed last year. This is the first legislative enactment dealing with the practical aspect of water conservation. The main provision is one setting apart a million sterling for the construction of hydraulic works within the next five years. As the working of this act will be so important, I will describe its provisions somewhat in detail:—The funds are to be expended on works under the following heads: State Works, Small Conservation Works, Trust Works, and Works under preceding acts.

The definition of a State work is not given in the act, but is left to be determined by the policy of the Minister. Any large works, such as storage reservoirs for balancing the flow of a large river, or extensive diversions from the rivers, or even the main channels of irrigation schemes, would naturally be classed as State works. Briefly, a State work would be any undertaking of some magnitude on which a number of smaller works might depend.

Expenditure on the small conservation works would be confined to such as could not be assigned to any particular district, such as works for the benefit of the travelling public or travelling stock.

Trust works form a most important feature of the act. The intention is to deal with every description of water supply, conservation, irrigation, or drainage work which would have a beneficial influence on some concentrated area. Under this heading would be included village water supplies, irrigation areas, whether supplied from rivers or main canals, weirs on streams or rivers, schemes of swamp drainage, or water supplies by artesian bores. After the construction of any such works, the people of the surrounding "Trust District" have the privilege of electing a majority of the Trustees to manage and maintain the works, the remainder are nominated by the Minister. Several sections of the act are devoted to the duties and powers of these Trustees, the principal being levying and collecting the rates to pay for the maintenance of the works, together with interest on the cost of construction. They are also required to form a sinking fund to pay off the capital cost within a stipulated number of years. Under the act, funds are available for carrying out works under any of the preceding acts.

Such are the legislative lines on which water conservation will be carried out during the next few years. I will now briefly touch on some of the aspects of the subject which have received little attention, but which are of the greatest importance.

The first question is, what portion of this State is capable of improvement by means of works of conservation? By reference to the map, it will be seen that the line of 20 inch rainfall is practically parallel to the coast-line of New South Wales and about 200 miles inland. That is to say,

that to the eastward of this line there is usually sufficient rainfall over the coastal strip, and such country cannot be said to be in urgent want of conservation works. At the present time, it may be said that the most pressing problem is the reclamation of the arid country to the west of the 20-inch line of rainfall.

There is no doubt that the area of irrigable land in the State is so large, that even if all the coastal rainfall were conserved and conveyed inland, it would be insufficient to reclaim one-tenth of it. It is therefore important that none of the water resources of the State should be wasted, in other words, the water should be reserved for the most suitable soils, and be applied in the most economical fashion. It would be a foolish policy to carry out large works without complete information as to the quantities of water available. For example, if an engineer is ignorant of the minimum flow, he is almost certain to design works which carry more water than can be continuously afforded. The result of such a procedure would be that in a dry year, just when the water was in strongest demand, the supply would fail, this single failure would destroy all confidence in the scheme, and progress would be retarded for an indefinite number of years. On the other hand, if he is ignorant of the maximum flow, the design of weirs becomes indeterminate, since they must be arranged to pass the highest floods without submerging the adjacent country to an extraordinary extent.

The whole of the arid portion of this State lies within the watershed of the river Murray, but of course, it is by no means of uniform character. Its hydrography will therefore consist of a complete investigation of all the various quantities of water passing down the various rivers and creeks for all seasons and rainfalls. It is quite clear that there is no fixed connection between the amount of a

rainfall and the discharge of that fall by the flow in a river, so that information is also required on such important points as evaporation and seepage. At the same time the hydrology of the subterranean supplies should be studied, so that all the water resources of the State shall be properly exploited. Along with these should go a systematic exploration of the country for sites where it would be possible to store water.

The compilation of this voluminous information has been in progress since 1884, when some gaugings of the flow of the rivers were taken. The work has been continued up to the present time, and will have to be carried on for many years to come. The discharges of high floods must be obtained before an engineer can design works with any confidence in their stability, and such floods sometimes only recur at long intervals. The periodic alterations in the courses of the western rivers also render repeated observations necessary.

Gauging the flow of the rivers is then, the most important hydrographical work in connection with water conservation in this State. Stations have been set out on all the principal rivers, and daily readings are taken at 35 of them. Complete discharges have been taken at some of them, and the remainder are being taken at every opportunity. A detailed account of this work has just been read before this Society, the position of the gauging stations is shewn on this map.

The discharges having been calculated for every foot of rise, a curve is drawn shewing the discharges corresponding to the height of the water. The total discharge for any period can then be obtained by keeping a record of the heights of the water-surface during that period. In this way the maximum, average and minimum yearly discharges can be obtained. The published records of rainfall give no clue to

the quantities of water ultimately available, as there are no rain-gauges on the highest peaks of the dividing range, where the heaviest rains and snows occur.

I should like to make a remark here on the vexed question of the unit to be adopted in measurements of flowing water. The natural and scientific unit derived from British measures is obviously the cubic foot per second of time. This unit represents a large quantity of water when converted into gallons per day, and since British water engineering has been chiefly concerned with town supplies, the smaller unit of a cubic foot per minute has crept into use. In irrigation work, however, it is convenient to have a unit which bears some simple relation to the area of ground irrigated. In America, the term "acre-foot" has been introduced as a unit of volume, it means, of course, the quantity of water which would flood an acre of ground one foot deep, or 43,560 cubic feet. A flow of a cubic foot per second, called a "cusec," will deliver an acre-foot in 12·1 hours, roughly, a cusec will give 4 acres of ground a 3 inch watering in a working day.

After having obtained a proper survey of the water resources of the State by long continued gauging, it will be necessary to utilize them in the most economical manner. This must be so, because the supplies will be used as a factor in the pastoral industry, and the margin of profit in that industry has descended to a low level. For many years to come, the most obvious use of irrigated ground wili be for growing fodder on which to feed sheep. Along with this might proceed the cultivation of small gardens for vegetables, and in this way the arid areas might be insured against bad seasons. It is quite clear that any schemes must be rigourously economical to ensure adoption.

It may be remarked that the occupation of the State by the pastoral industry has produced important changes in

the natural conditions. It is certain that the Murray watershed now responds to rainfall much more freely than it formerly did, and no doubt this effect has been produced by the puddling of the surface by the trampling of stock. Also, tracks to watering places become small tributaries during rainfall. With regard to the extensive ring-barking which has been indulged in by all the pastoralists, it is more difficult to trace cause and effect. There does not appear to be any evidence to shew that the destruction of forests causes a diminution of the rainfall, but there is no doubt that the presence of bush causes a catchment to run off during a longer period, thus increasing the low flow in the rivers. Trees and bush also prevent erosion of the soil, and this is a most important point, some large storages have already been spoilt by the quantities of silt carried into them. The importance of shade trees, both for man and beast, has not yet been recognized in the country, and forest conservation is in a most backward state. The most profitable policy would be to arrange that the conservation of water and trees should go hand in hand.

The last few dry years have conclusively proved that before any large diversions can be made from our rivers, it will be necessary to construct large storage reservoirs to supplement the flow in bad seasons. As may be supposed, the opportunities for storage are different on each river. When the river flows continuously throughout the year, the fluctuations can be controlled by a capacious storage at the head. This would usually be made by building a high dam across the stream, preferably at a point where the channel runs through a narrow gorge. When the location permits of the water being led out by a cutting and brought to the surface of the country by gravitation, the problem of irrigation at once becomes easy and profitable.

A most difficult case is that of a river which dries up altogether for long periods. In such circumstances it is best to construct the storages continuously in the bed of the channel, leaving them to be filled by the periodical floods. Only a limited supply of water can be retained by such means, and irrigation would generally have to be done by means of expensive pumping. Speaking broadly, the condition of the majority of our rivers is such that a combination of both these methods is required to give the best results. A most important point to be attended to in designing storages, is to secure the greatest possible depth. If a site includes large areas, which can be only lightly submerged, it is advisable to bank them off from the reservoir, otherwise they will form mere evaporating pans.

The subject of evaporation is of importance in a country where the maximum rate seems to be as high as in any part of the world. Experiments with small iron tanks have been carried on for many years, and a fair assumption from the published records would be that the maximum rate might be about 6 feet per annum. Unfortunately, there is no connection between the evaporation from a small experimental tank and the evaporation from a large sheet of water exposed to the accumulative action of a sweeping hot wind. An opportunity lately occurred to obtain the actual rate from a large sheet of water at Cobar under natural conditions. The observations extended over 3 years, and the result shewed that between 10 and 11 feet of water was lost from the reservoir every year.

The importance of depth in a reservoir was also forcibly brought out in the following case:—It lately became necessary to select a site in a dry portion of the State where the evaporation had been assumed to be 6 feet per annum. Two locations were available, one with a depth of 35 feet, the other with a depth of 70 feet. The first

would hold 14 hundred million gallons, the second only 12 hundred million gallons, and as the water was required for town supply, it would, at first glance, seem that the larger reservoir was the more desirable of the two. Another view of the case is that the evaporation alone would dry up the reservoirs in 6 and 12 years respectively. Fortunately, the records of an existing reservoir in the neighbourhood were available, and these shewed an annual loss of $7\frac{1}{2}$ feet by evaporation during the past 10 years. Applying these figures to the two cases revealed the fact that if the larger reservoir had been in existence it would have failed three times, and would have been in a low condition for 3 years out of the 10, but if the smaller one had been in existence it would have overflowed three times, and would have been from half-full to overflowing during 8 years out of the ten. The losses by evaporation in this case were much larger than the town supply, so that the ultimate choice fell on the deep reservoir in preference to the more capacious one.

Another important question which can only be settled by actual experience, is that of the effectiveness of a watershed. It has been the custom, hitherto, to take the results of European experience, and consequently some mistakes have been made. It is only quite recently that the Department has been able to collect any systematic information on the subject, but what has been acquired shews that further research will not be a waste of time. The following is a typical case:—

A concrete dam was built to form a storage reservoir in a fairly humid district. The annual rainfall was 27 inches and the catchment area was 1,500 acres. As this area was covered with slate and possessed steep slopes, it was considered fairly impermeable, and no difficulty in filling the 40 million gallon reservoir was anticipated. The annual

rainfall on the area of the catchment, would as a matter of fact, fill twenty such reservoirs. After the dam was finished, it took over a year to fill up to top-water-level, and during this period careful observations were made of the rainfall, and the corresponding height of water in the reservoir. An analysis of these returns has been made, and it discloses some remarkable facts. During 7 months from August to April, the rainfall amounted to 17 inches, yet the reservoir gained nothing, but on the contrary, lost 4 million gallons. In the month of January alone, nearly 5 inches of rain fell, yet the amount which ran into the reservoir was less than one million gallons. The explanation of course, is that the rain was absorbed by the heated ground. In the following May when the weather was cooler, the rainfall was nearly 4 inches, and 7 million gallons of water were impounded, although this is a more satisfactory result, the quantity impounded is only 5% of the fall. In the next month, June, another 4 inches of rain fell, and no less than 23 million gallons were impounded, this amounts to 17% of the fall. In the next month, July, an inch of rain sufficed to fill the reservoir to overflowing, so that the observations were abruptly ended, but on this occasion it is certain that over 25% of the fall must have run off the catchment. The conclusions to be drawn from this seems to be that summer rains will not flow off this catchment, so that half the annual rainfall may at once be put aside as entirely lost. Of the winter rains, it may at once be said that from 5% to 25% is available if they fall at the right time. Taking the whole year round, it appears that this superior catchment delivers less than one-two hundredth part of its water into the reservoir, a startling fact which may well enjoin caution in any future selections of storage sites.

I will now leave the subject of surface waters and briefly touch on the underground supplies which are of almost equal

importance. Artesian water is rainfall which is absorbed on the slopes of the coastal ranges, and then finds its way inland under the plains by subterranean passages. The proved Artesian Basin is shewn on the map, and the area enclosed in this State is 62,000 square miles. The area of the upturned edges of the intake beds in the ranges has not yet been accurately defined, this is a matter for the geologists, and a proposal is now before the responsible Minister to have this work proceeded with as soon as possible. In the absence of this information it is quite useless to form any estimate of the quantities of artesian water available in the State. At the present moment, it does not appear that the supply is likely to fail or diminish seriously under the moderate demands so far made on it, and it cannot be lost by evaporation. It is a fact that the discharges of many of our bores have decreased of late years, but this is undoubtedly due to local causes, such as the silting up of the channels near the bore, or the escape of the water into another strata.

The investigations which are being carried out are to afford an accurate record of the flow at different levels above the surface. In other words the hydraulic grade of the underground flow is to be determined. Some of the existing bores fluctuate from day to day, and it is also proposed to make observations on these over extended periods. The direction of the underground flow can be plotted by determinining the lines of equal hydraulic pressure, and the completion of this work will settle the vexed question of the outfall into the ocean. The pressures of each bore will be taken by means of a gauge, and the flow will be estimated by passing it over a weir or notch.

In addition to the artesian supply there are sub-soil supplies all over the State. It is highly propable that these are fed by percolation from the rivers, and as the depth

below the surface is generally small, it may easily happen that this cheap and simple source of supply will prove the proper one to develope large areas of the country.

I will now give a general description of the principal rivers, the works which have so far been carried out, and the works which are now in contemplation.

The Murray River has an effective catchment area above Albury of 7,000 square miles, the larger portion being in Victoria. The contribution of flow by each State is, however, equalized by the superior rainfall and the higher ranges of New South Wales. The gradient of the river at Albury is about 1 foot per mile, diminishing to $3\frac{1}{2}$ inches per mile at the South Australian border, and $2\frac{3}{4}$ inches per mile at Blanchetown in South Australia. Up to the present the only works constructed by this State are diversion cuttings into Tuppal, Eagle and Gulpa Creeks. There are also two large irrigation canals under consideration. The first leaves the river near Albury, the other leaves near Tocumwal. There is not sufficient water avilable for both schemes, and an investigation is proceeding to determine which would be the most profitable for the State to adopt. The first canal would command 1,000,000 acres of fine land out as far as Deniliquin, but it will be perceived by reference to the map, that portion of this area is on the line of 20 inch rainfall and cannot be classed as arid. It is therefore doubtful if the landowners would be willing to bear the cost of such a scheme, when the water would be only used as an insurance against dry weather. The Tocumwal canal on the other hand, traverses country with about six inches less rainfall, and the area it would command might extend to Balranald.

As stated before, large storages will be required before any comprehensive diversions can be made. Sites for the storage reservoirs have been surveyed at Cumberoona and

Talmalmo with capacities of 25,000 and 19,000 million cubic feet. Irrigation by pumping is now carried on along the banks of the Murray to a considerable extent. This is possible on account of the low banks which render the pumping inexpensive.

The Murrumbidgee River has an effective catchment area of 13,000 square miles. The grade of the surface is about 10 inches to the mile at Wagga, and diminishes to 5 inches to the mile below Hay. At a point about 20 miles below Hay the banks decrease in height and the river spreads out over 1,000 square miles of low lignum country. Up to the present, the only works constructed are the cuttings into the Yanko Creek. There are four proposed irrigation canals under consideration now, two on each bank of the river. The first pair take out from the river at Narrandera, the second pair from immediately below Hay. Both projects command scattered areas suitable for irrigation, but there is also a large area of clayey country included. The water supply is sufficient for two of the canals only, and it is a question for urgent consideration as to where the water can be utilized to produce the greatest good to the State. The problem is complicated too by the presence of large sub-soil supplies between the Murrumbidgee and the Murray to the west of the Yanko Creek, but a classification of the land is now in progress. Storage sites have been surveyed at Tantangarra and Barren Jack, the capacities of which are 16 thousand million cubic feet and 28 thousand million cubic feet respectively.

The Lachlan River has an effective catchment area of 20,000 square miles. The grade of the surface is about 15 inches per mile at Forbes, and diminishes to $4\frac{3}{4}$ inches per mile at Oxley. Below Oxley the channel widens out into reed beds, in which the river is lost. The river also overflows into Lake Cowal, and into the Willandra and Billabong

Creeks, so that the bulk of its flow is really spilled over the country. The works constructed up to the present time are:—A weir in the river with a cutting into Booberoi Creek, a cutting into Lake Cudgellico for storing flood water in the lake, the effective capacity being 1,000 million cubic feet, a weir in the river and a cutting into the Willandra Creek, this supplies the country between the Lachlan and the Darling. A very limited amount of irrigation only is practicable from the Lachlan, and the i olated areas which are irrigable are too small to justify the construction of gravitation canals.

The Lachlan frequently stops running in dry seasons. The flow below Booligal ceased some 14 months ago and is still now dry, there has been no flow past Hillston for the last 12 months. It is proposed to conserve the supply by means of a series of low weirs in the river, these will form pumping pools for the limited amount of irrigation which can be practised. When the demand for water has increased, a storage could also be constructed at the head of the river, and its water could be used to replenish the pools. The site for the storage has been surveyed below the junction of the Abercrombie River, its capacity is 12,000 million cubic feet.

The Bogan River has an effective catchment of 5,000 square miles. The fall in the channel decreases from 15 inches per mile at Dandaloo to 12 inches per mile at the Darling. The channel is wide and shallow, and runs only at long intervals. It is doubtful if there is sufficient water available for any irrigation beyond small gardens or orchards for household purposes. Proposals are in hand for the construction of weirs in the river channel, this is the only means of conserving water on this river.

The Darling River has an effective catchment of 105,000 square miles. The fall in the channel decreases from about

1 foot per mile at Mungindi (Queensland border) to 3½ inches per mile at Bourke. As far down as Wilcannia the channel is very deep, affording no facilities for diversion canals, and rendering pumping schemes expensive. From Wilcannia to Wentworth the banks decrease in height, and there are large ana-branches. Facilities for irrigation only exist along this portion of the river, where large areas of lake beds may be supplied by gravitation. The only work so far carried out is an experimental lock and weir at Bourke. The irrigation of the beds of Lakes Cawdilla, and the great ana-branch from storages in lakes Menindie and Pamamaroo is now under consideration, it is thought that 30 thousand million cubic feet can be stored in the two latter, but of course the losses by evaporation will be very great. The Darling is fed by tributaries which are dependent on the monsoonal rains, and in consequence its flow is much more unreliable than the flow of the other rivers which are fed from the coastal range. It frequently stops running for long periods, the freshet of last January being the first flow for twelve months.

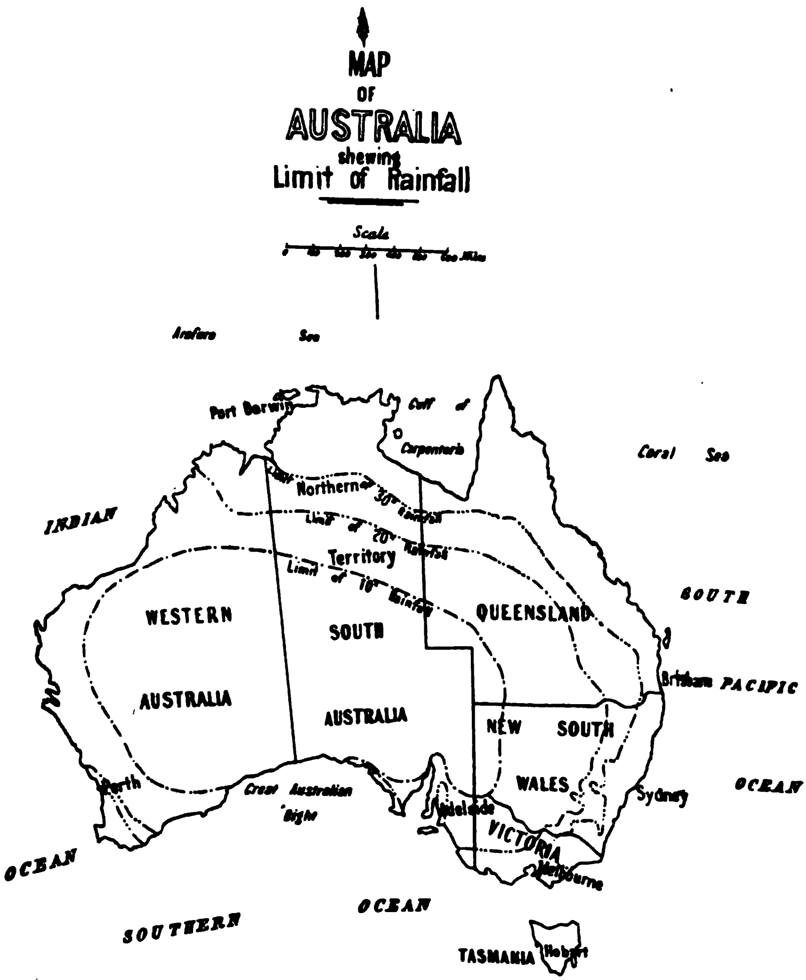
The tributaries of the Darling north of the Bogan, traverse the artesian basin, and the artesian supply is more reliable than the flow of either the Macquarie, Castlereagh, Namoi, Narran, Gwydir, Bokhara, Culgoa, Warrego or Paroo Rivers. It is probable that these tributaries are of more value in maintaining the flow of the Darling than in their own channels. Advantage has been taken of the Macquarie being on the fringe of the basin to make diversions into Cunningbar and Duck Creeks, which flow outside the artesian area. The only other works constructed at the present time are the diversion cuttings on the Gwydir River, which serve the double purpose of draining land subject to inundation and supplying a network of creeks with water.

The artesian area is divided by the Darling or Barwon into two divisions, the western being under the control of the Western Lands Board. Under the long leases now granted by the Board it is probable that artesian boring will be carried out by private enterprise, leaving only public watering places to the care of the State. In the Central division where the policy of closer settlement prevails, it will be necessary to map out the country into Trust Districts and construct the works. At present it is only possible to arrange bores to give supplies for stock, a small surplus being also available for small irrigation, but when the demand for irrigation increases, it will be necessary to sink more than one bore in each Trust District.

The recent drought has had a valuable educative influence on the settlers, and I have no doubt that the next few years will see a large number of works carried out both by the State and by private individuals. Private works are amply safeguarded by the Water Rights Act, and State works can be carried on with confidence so long as they are an insurance on the prosperity of the country.

Proposals have recently been put forward for the construction of large irrigation schemes by private enterprise. It is debateable whether such works should be allowed to pass out of the hands of the State. The area which can be commanded by gravitation from our rivers is largely in excess of the water supply. The land is of variable quality, some of it is excellent for irrigation and some of it is quite unsuitable, portions of it have a good rainfall and other portions are served by railways. Some of it, if irrigated, would justify the construction of new railways. On the whole, I am of opinion that no large irrigation schemes should be approved until a thorough classification of all the included land is made. This restriction should apply to all

schemes, whether initiated by private enterprise or by the State.



THE HIGH SPEED ELECTRIC RAILWAY TRIALS ON THE BERLIN ZOSSEN LINE OF 1901, 1902 AND 1903.

By C. O. BURGE, M. Inst. C.E.

[*Read before the Engineering Section of the Royal Society of N. S. Wales, November 18, 1903.*]

(*Abstract.*)

THIS paper is a sequel to that read by the author last year, before the Society, on "Recent developments in high speed railway construction and working," and contains information regarding the trials referred to in it, not then available. The trials took place in 1901, 1902 and recently, on a line near Berlin about 14 miles long, having very easy grades and curves. An existing power house 8 miles from the line was utilized for the supply of the 3 phase alternating current required, this being conveyed by 3 overhead feeders to the line wires, the return being through rails and a cable.

The rails, laid to the standard guage of 4 ft. 8½ in., were 67·33 lbs. to the yard, and the road was of the ordinary pattern in use in Germany. For the first experiments, two single cars were designed, in friendly rivalry, by the Allgemeine Elektricitäts Gesellschaft and by Messrs. Siemens and Halske respectively. They were generally alike, as regards the power, of four 250 HP motors, capacity for 50 passengers, and form, of about 70 ft. long by 9 ft. 4 in. wide, and in resting on two six-wheel bogies, the wheels being 4 ft. 1$\frac{3}{16}$ in. in diameter, and making 853 revolutions per minute for the speed aimed at, viz., 124 miles per hour. The bogie wheel base was 12 ft. 5½ in. The motors, in both cars, actuated the leading and trailing axles of each bogie. There were, however, important differences in detail which will be referred to later.

To ascertain the principal requirements, both firms made certain experiments, in the shops, to ascertain the amount of the two resistances, friction and air which would have to be overcome at the proposed speed. It was determined that 10 lbs. per ton would be the rolling friction, though not much information was given as to how this was arrived at. As to the air, the Siemens and Halske Co. constructed an experimental fan, details of which are given in the paper, which, driven at the rate of the proposed speed, showed that about $18\frac{1}{2}$ lbs. per square foot in still air, would be encountered, this amounting to just double the resistance of the rolling friction. These results showed that 950 HP. was required to maintain full speed, so that 1,000 HP. was fixed upon for the motors, but they were designed to be capable of three times this for a short time, to provide for starting and accelleration.

The body of the cars, which is bevelled top and sides, at each end, to diminish air resistance, is divided into end platforms for the driver, a central compartment for the transformers and other electrical equipments, and the two intermediate spaces are cross-seated for 50 passengers. The brakes were on the Westinghouse system, but for emergencies the electric current was made available.

The principal differences between the two cars were in the following details: the A.E.G. car collected the current by two sets of three sloping rods, differing in length and inclination, each set swivelling from the roof over each of the two bogies. Contact was made with each of the 3 wires, which were in the same vertical plane, by bows at the end of each pole, the pressure being maintained by springs. There being two sets of poles, there were therefore six contacts.

The three-phase current was led to the two transformers at centre of car, and, after reduction to a suitable voltage,

to the motors. The rotors were fixed on hollow shafts encircling the axles and not rigidly attached to them. Three pairs of radial laminated springs connected the hollow shaft of the rotor, in each case, to the periphery of the wheel, so that the vibration and jarring inseparable from a rigid connexion was avoided. The weight of the loaded car was about 80 tons.

In the S. and H. car, the collectors were formed of two vertical Mannsmann masts $7\frac{7}{8}$ in. in diameter, fixed in sockets in the floor, near each end, and protruding through the roof to above the level of the overhead wires. To each of these three arms, collecting bows, all in the same vertical plane, were fixed, making the three contacts for each pole with the wires. They were not only provided with springs to maintain the contact, but had a special apparatus with a wind plate, so that the reaction of the air was made to assist in the same duty.

The current was reduced by the two transformers placed in the centre, to the four three phase motors, the normal full speed voltage of which was 1,150. Each motor weighed about 4 tons, and their rotors were rigidly fixed to the four driving axles. The weight, fully loaded, was $93\frac{1}{2}$ tons, of which 41 tons was accounted for by the electrical equipment. The average weight on each axle was therefore 15·6 tons as against 13·33 in the rival car. No trouble appears to have arisen in either car in securing sufficient contact at the highest speeds.

A brief description of the trials of 1901 is given in the paper, from which it may be noted that the maximum speed attained then was 99·40 miles per hour, by the S. and H. car with voltage of 10,800 and 36 periods. The full acceleration, for which a possible output of 3,000 HP. was provided, was not taken advantage of, owing, it is said, to the inability to meet this requirement at the power house

in the requisite short period of time. As to retardation, the maximum speed at which tests were made was at 98·2 miles per hour, when a stop was made in 1 mile, and in 67 seconds, or about 2 ft. per second per second. The maximum retardation however was when 78·9 miles per hour was reduced to nil in half a mile, and in 45 seconds, being about 2½ ft. per second per second.

Figures were given as to the consumption of energy, but none seem to have been recorded for the maximum speed attained, but for 87 miles per hour, uniform speed, 7·47 kilowatt hours per mile output at the power house was noted. Owing to the distance, it is said, of the origin of the power, 8 miles from the line, only 67% of the output there was available at the rotor shafts.

Air resistance was measured by an apparatus fully described in the paper, the average results satisfying the following formula where the symbols represent lbs. per square foot and feet per second

$$r = 0{\cdot}001334\ v^2$$

The motion of the cars was very steady and smooth in all the trials, up to about 80 miles per hour, but over this, the weakness of the road began to show, and it was stated that the 100 miles per hour was not exceeded on this account, and not to any deficiency of the motive power or in its application.

Some months later in June 1902, an electric locomotive which had been designed for the purpose was tried, but very high speeds do not seem to have been aimed at or attained. The weight of locomotive and car together, particulars of which are given in the paper, was only 76 tons including passengers. The normal power, which was through two motors, was reduced to 800 HP. The main difference however, was in the transmission of the current direct to the motors, without transformation.

Details of the trials of 1903 are not yet to hand, but we have learnt by wire that 125 miles per hour were attained early in October, and 128 about three weeks later. This if practicable in Australia, would bring Sydney within $4\frac{1}{2}$ hours of Melbourne.

The following is an abstract of comments written before this news was received:—Having in view the interest with which these Berlin trials have been looked forward to by railway engineers all over the world, attention was drawn to their somewhat incomplete and unsatisfactory character. Such, for instance, as the obviously too light character of the road, and the delay in remedying this comparatively small matter. The very moderate amount of acceleration and retardation reached, a most important matter, especially in suburban traffic. The absence of particulars of these and of power consumed in the maximum speed, and finally, the want of reports on the comparative smoothness and vibration of the gearless and spring connected drivers of the two cars. The experiments did show, however, the practicability of transmission of current by overhead wiring at very high speeds.

The paper concludes by dealing with the general question of adopting very high speed to the following classes of passenger traffic viz. (1) city and suburban (2) connexion without intermediate stoppage between two populous centres, at a moderate distance apart, and (3) long distance trains.

It is shown that as regards No. 1 quick starting and stopping are the chief requisites, and the instance is given of the Liverpool overhead railway with its stations averaging $\frac{1}{3}$ mile apart, the stoppage being only 11 seconds at each. A through speed of 19 miles per hour is obtained by employing and acceleration and retardation of 3 feet per second per second. The effect of such working on a line

from Strathfield to the centre of Sydney, should such extension be made was shown, and the necessity of passengers displaying more smartness in entering and leaving the cars than they do at present, if such were to be carried out.

To the second case, high speed electric traction was shown to be especially applicable, and the Manchester and Liverpool line, now about to be constructed, and others in contemplation, showed this. For long distance traffic, the steam locomotive, owing to many causes, among others the large amount of capital invested in locomotives and their appendages, is not likely to be discarded for many years to come.

It was shown that, to ensure safety at such high velocities, it was necessary, where applicable, to have single car trains, uniform speed and headway, absence of points and crossings except at termini, extra effective fencing and watching, and a solid road.

The speed was shown by the example of the Berlin trials not to be as costly, per passenger, as might have been expected, and it was pointed out also that in long distance traffic enormous saving would be effected in largely abolishing heavy dining, kitchen, and sleeping cars, which would be unnecessary in making journeys in 3 or 4 hours now occupying 8 to 10. In this connexion it was stated that there were now 60 dining cars leaving London alone daily. The paper ended with stating that the fast passenger traffic of the future would no doubt be on the lines of the Berlin trials.

RELATION OF ELECTRICITY TO IRRIGATION WORKS AND LAND DEVELOPMENT.

By THOMAS ROOKE, Assoc. M. Inst. C.E.

[*Read before the Engineering Section of the Royal Society of N. S. Wales, July 20, 1903.*]

IT is my privilege to night to bring before you the application of electricity to irrigation works in Australia. The time at our disposal will not permit anything more than a passing glance at a subject of such magnitude, and the following remarks are intended to draw attention to possibilities of electrical development in this direction. The subject is inseparably associated with the transmission of power by electricity for all kinds of industrial purposes. It is proposed first of all to draw attention to electrical pumping plant; secondly to the transmission of electricity and its development; thirdly, to consider the relation of these matters to conditions prevailing in Australia.

Pumping operations of all kinds, both on a large and a small scale, are being carried out to day by means of electricity, for irrigation, for mining, and for general purposes of all kinds. Speaking generally, there is nothing peculiar about the pumps used, and the motor has generally been attached by spur belt or other suitable reducing gear. In most cases now arising, it is possible to dispense with gearing, for manufacturers have succeeded in lowering the speed of motors and raising the speed of pumps to the extent necessary. The ideal pump for attachment to an electric motor is the centrifugal pump, in which valves are abolished and the greatest simplicity attained. High and low lift motor driven centrifugal pumps, the former of small size have been in use for a good many years, but it is only

recently that the principal objection to the centrifugal pump, namely its inefficiency, has been largely remedied. This improved pattern somewhat resembles an inverted water turbine, and lifts of 250 to 300 feet are attainable by a single impeller, with an efficiency of 65 to 75%. For higher lifts, two or more impellers are placed in series, the number used depending on the speed of the motor, the lift etc. The pumps can also be arranged in a cascade, and excessive pressures on packing glands avoided.

With the introduction of polyphase electric currents, the motor has also been greatly simplified, the commutator abolished, and the voltage which can safely be applied greatly increased. These improvements are of especial value in decreasing the attention required by the plant and increasing the efficiency of operation at great distances. Such a plant can be operated and controlled from a distance, is exceedingly small and portable for the duty it will perform and requires very little protection. For many ordinary purposes, for mining work, and even in power houses using steam, electric pumps have replaced steam pumps, and it has been found that their higher efficiency has justified the greater first cost and the double conversion of power. In mining work the saving effected by electric pumps, has, under many conditions been remarkable. Centrifugal pumps can also be regulated very simply by means of the delivery valve, and the loss of efficiency arising from throttling the delivery is not nearly so great as might be supposed. If the delivery pipe is throttled, the power taken by the motor is also decreased, and if the delivery is closed entirely, the impeller churns but does not give rise to excessive pressure, whilst the motor absorbs a very much smaller power than is required when water is being raised.

Irrigation works by means of electrically operated pumps are now in use by the Kern County Land Company of Cali-

fornia, and electricity is also being supplied for the same purpose from transmission lines in the neighbourhood of Los Angeles. There is a large tract of land in the Kern Valley where there is no surface water for a large portion of the year, but a plentiful undercurrent which can be reached by wells 60 feet deep.

Power is transmitted at 10,000 volts pressure to pumping stations, which contain step down transformers to 500 volts and a 30 to 40 HP. induction mot r. Centrifugal pumps of special design are used. The motor is coupled direct to the pump by means of a vertical shaft, the pump being placed some 18 to 20 feet above the water, and the motor at a convenient height above ground level. The suction is brought in on top of the pump so as to relieve the weight of moving parts on the step bearing, for which suitable automatic oiling arrangements are provided. It is found that a 30 HP. motor will pump enough water to irrigate a square mile of land, the lift being 25 feet. One man attends to 8 or 10 pumps, which are visited once or twice a day.

The pumps are run very nearly continuously, but are shut down for short periods when there is shortage of power owing to the demand for light. The same company have under consideration a further extension of the system for operating stock wells by means of $\frac{3}{4}$ HP. motors, which would be attached to pumps now driven by a boy and a mule. The estimated cost of 120 pumping plants and 120 miles of pole line being £12,000.

An investigation recently carried out by Mr. J. B. Lippincott, Hydrographer of the Geological Survey in California, showed that some 650,000 acres of land could be irrigated at an estimated cost of $8 per acre. The water would be obtained from storage reservoirs and electrically operated pumping plants. The estimated addition to the taxable property of the state, irrespective of town and city property, was $20,000,000.

An extensive pumping and general power service is provided from the electric transmission lines of the Edison Electric Company of Los Angeles. These consumers absorb the largest aggregate of power. Many of the plants consist of deep well pumps of ordinary types, but the majority are centrifugal plants working singly, on the shallow wells, and tandem on the deep ones. Some lifting water 100 to 150 feet. Many of these pumps are said to have been working for the last seven years without repairs, and the reliability and cheapness of the service is such that gasoline and steam engines are rapidly being displaced. One man tends to operating seven pumping plants, besides performing other duties.

Within the last two or three years, irrigating pumps have come into extensive use in Volo County, California, and are operated from the transmission lines of the Bay Counties' Power Company. An abundance of excellent water exists within 20 feet or so of the surface, and this is now being pumped for irrigating orchards. The plants are of various sizes, 20 HP. units being about the average, and are in operation all but continuously from May to November. At the rates charged for electricity and labour the cost of irrigation varies from $2 to $2·50 per acre, according to the character of the soil and the depth of the well, and numerous instances are said to exist in which irrigation has increased production by 75%, and on a fair average estimate by not less than 40%.

The application of electricity for purposes of irrigation is therefore no new thing, and is without doubt practicable wherever there is water to pump and power to be transmitted. The commercial aspect of such a scheme depends on other conditions which vary more or less in each different locality. From an article by Mr. McKinney on the subject of irrigation, it appears that there are many areas

in Australia which will well repay a capital outlay of £20 per acre on pumping plant, and such areas even if small and scattered, can certainly be reached by overhead electric transmission lines.

The question arises, what has been and is being done in regard to power distribution over large areas by means of electric transmission. There is at present taking place in England a most remarkable development in this direction. During past years, large industries have been built up in manufacturing centres, and coal has been conveyed to them as required, and there consumed for generating power.

At the present moment power distribution companies are busy erecting power houses on or in the neighbourhood of the coalfields, for the purpose of transmitting electricity to the industrial centres. Their existence depends on the fact that it is cheaper to generate, transmit, and apply power by means of electric motors than to transport, distribute, and consume coal under distributed power plants.

In England, it is not only necessary that this should be the best and cheapest method of transmitting and applying power, but it must be so much the best as to justify the abandonment of existing power plants. The following are some of the more important of these Companies: The South Wales Electric Power Distribution Co., to supply an area of 1,050 square miles. The Shannon Water and Electric Power Company, with an area of 2,800 square miles. The Derbyshire and Nottinghamshire Power Co., with an area of 1,570 square miles. The Yorkshire Electric Power Co., with an area of 1,800 square miles. The Leicestershire and Warwickshire Electric Power Co., with an area of 1,340 square miles. The Kent Electric Power Co., with an area of 1,485 square miles. The Cornwall Electric Power Co., with an area of 1,100 square miles, and seven other smaller companies.

The reason why these areas are not much larger is not due to any electrical difficulty but to the density of the demand which has to be met, and in all these schemes electricity will be transmitted through underground cables which cost a great deal more than the overhead lines used in America, and necessary where the demand is scattered.

In America, development of territory is being carried out on a much larger scale than elsewhere, and electrical lines distribute power for this purpose. The areas to be covered are very great, and compare in this respect with Australia. The longest transmission lines are to be found in California and are being operated by the Bay Counties' Power Co. and the Standard Electric Company. Power houses have been erected at Colgate and Electra, and electricity is transmitted over a distance of 211 miles to San Francisco, or 140,000 square miles of territory are within reach of a single power house, and even longer and larger transmissions are contemplated. From twenty-two such stations transmission lines could be extended over an erea equal to the whole of Australia. At Colgate and neighbouring power houses 25,000 HP. is developed. At Electra the Standard Company have 15,000 HP. and are now adding 21,000 HP. The system on which these power transmissions are operated is as follows:—The generators supply electricity at 2,300 volts to static transformers which step up to 40- 50- or 60,000 volts. The transformers are grouped and delta connected on the low tension side. The high tension windings are star connected, the centre of the star being earthed. The insulation of each conductor has therefore to withstand a normal E.M.F. not exceeding 35,000 volts to earth. The poles are of cedar from 25 to 60 feet in height, the insulators are of brown glazed porcelain having a very large surface. These are supported on wooden pins and wooden cross arms. The weight of overhead con-

ductors between Colgate and Oakland is about 6 tons per mile, copper being used. On the lines between Electra and San Francisco stranded and solid aluminium conductors have been used.

At points where electricity is required these transmission lines are taken into substations, the voltage reduced by static transformers, similar to those used for raising the voltage at the generating stations, and if continuous currents are required for traction purposes, motor generators or rotary converters are used to transform the three phase alternate currents. Turning to the Continent of Europe and to India, it will be found that similar electric transmission schemes are in existence and are being further developed, although the distances are nowhere so great as in California. With regard to the sources of power for transmission, there is a very popular impression that water power is the only source of cheap power, but as a matter of fact there are not unfrequently circumstances in which coal is a more economical source of power than water, even where present in abundance.

There is an instance of this in Australasia, the capital cost of this plant has been roughly £184 per kilowatt installed, the distribution being carried out by overhead lines which are not costly. Now £100 per kilowatt installed is a good price for an electrical plant operated by steam and having underground cables, which are much more costly than overhead lines, and there are instances in England where the capital cost is as low as £60 per kilowatt installed. The cost of the water and transmission line may therefore be taken as £84 per kilowatt installed. The output of the plant has been 1,600 units per kilowatt installed per annum, and this quantity of electricity can without doubt be generated by a good steam plant for a consumption of 4 tons of coal. The cost of this coal would

have been equivalent to about 5% on the £84 per kilowatt expended on utilization of water power, and in addition to this there are the extra costs of maintaining the transmission line and the loss of power in transmission. In this particular instance it is not easy to see that any great advantage has been derived from the use of water power.

The load factor is low, for each kilowatt of machinery might have generated say 7,000 units instead of 1,600 units in which case the water power would have had an advantage over steam power, but up to the present it has not been possible to obtain this load factor owing to the nature of the demand.

California possesses not only splendid water powers but possibly also the finest liquid fuel of the world, the discovery of which is recent. In San Francisco at the present moment, there are in operation not only the transmission companies but also the Edison company using liquid fuel to operate steam plant. Up to the present time the water power plant has not killed the steam plant, nor is there any apparent likelihood of its doing so.

Some interesting figures on the comparative costs of electricity produced under different conditions have been collected by Mr. J. B. C. Kershaw, and it may not be out of place to quote some of them here. Taking the best results obtained by means of water power, gas and steam, he arrives at the following figures, representing the cost per electrical horse power per annum.

Source of Power.	Lowest Estimated Cost. £	s.	d.	Country.
Water	1	5	5	Canada.
Steam	4	18	8	England.
Gas (blast furnace)	4	1	7	Germany.
Gas (producer)	5	0	0	England.
	Lowest Actual Cost.			
Water	1	19	0	Switzerland.
Steam	4	17	7	U.S.A.

These figures support the opinion now generally held that water power when developed without excessive capital expenditure is the cheapest source of mechanical or electrical energy. When however the hydraulic engineering expenditure has been heavy, the margin between the relative costs of water and steam power is greatly narrowed and sometimes disappears entirely.

Electrical energy generated by falling water is costing more at Rheinfelden at Zurich and at Buffalo than it would cost in South Lancashire if generated by steam power in large units, and the margin between the actual charge for water power at Niagra and the estimated cost of steam power in large generating stations in South Lancashire is only 12/- per E.H.P. per annum.

Since these figures were collected, great improvements have been made in the operation of steam driven plants, larger units have been built and the steam turbine has come into greater prominence, bringing with it lower capital cost. Coal handling apparatus and automatic labour saving machinery has also been improved, and the cost of producing electricity from coal has been lowered in consequence.

A still more recent development and one which bids fair to have great influence on future power schemes, is the Mond gas system, which provides probably the most perfect means of consuming fuel, and under proper conditions the most economical means of producing electricity from fuel.

Gas engines of 1,000 H.P. are in daily and successful operation, and larger sizes are now being built. These large engines are not operated with illuminating gas but with blast furnace and producer gas having a low calorific value. The generation of electricity by gas engines has not been adopted to any great extent, although many attempts to do so have been made. Hitherto the saving has been inconsiderable and has not compensated for other

difficulties, but the recovery of about 90 lbs. of sulphate of ammonia per ton of slack coal consumed in the producer promises to give this system a decided advantage over steam plants. There is however no conclusive experience on the subject at present, and a large power plant operated by means of gas engines using Mond gas would be to some extent experimental.

From the above it is clear that electrical pumping plant for irrigation works, the transmission of electricity over long distances with economy, and the economical generation of electricity in bulk by means of coal are not only practicable, but that such systems are in successful operation at the present time. Up to the present nothing of the kind has been attempted in Australia.

The power resources of Australia are her coal fields. These occur to a greater or less extent in every State and they are probaby more extensive than is as yet known. They present the means of producing electricity under conditions which are in some respects more favourable than those prevalent in England, where so much progress in this direction is being made. In many places the coal is much nearer the surface, and there is no invested capital to be written off by reason of the adoption of a new system, but a clear field.

One of the most important factors in the economical production of electricity is the load factor, and irrigation works offer a means of obtaining the best possible condition in this respect. The load factor determines the cost of fixed charges per unit of electricity produced, and hitherto it has been capable of great improvement, even where tramways, lighting and power loads have all been supplied from one plant. Irrigating pumps could be operated with equal advantage at all times of the day, and could be shut down during those hours when other demands were greatest.

In this manner there would be the means of obtaining the best possible load factor and electricity could be produced under the best and cheapest possible conditions.

Assuming that a suitable tract of country can be found not far from coal supplies, with a fertile soil, and water which only needs pumping, electric transmission lines could be run overhead to pumping stations, and from the same lines power could be provided for operating interurban light railways, lighting townships, driving saw mills and other machinery, and in fact for all those purposes to which electricity is at the present moment so widely and usefully applied. Such a system need not necessarily involve an enormous capital outlay at the commencement, for the system is flexible to a degree and capable of extension to almost any extent as may be necessary.

The first long distance transmission was between Lauffen and Frankfort, over a distance of 106 miles, and the following results were attained: At an E.M.F. of 25,000 volts from line to line, or 14 to 15,000 volts between each line and earth 180 horse power could be transmitted with an efficiency of 75% through conductors weighing about 11 cwt to the mile. This enterprise was carried through successfully ten years ago, since when many improvements have been made and higher efficiencies of transmission attained.

In California many prophesied disastrous failure for the transmission companies, but experience has proved the existence of a demand for power far in excess of all anticipations, and the difficulty is not so much to find the customers as to find power for them. Why are not developments of this nature possible in Australia? Is it absence of water, absence of suitable climate, absence of fertile soil or absence of enterprise?

So far as the cheap production of electricity, and its economical transmission over long distances are concerned, these are matters which are no longer experimental or doubtful, but can be determined with a high degree of accuracy, when the conditions and requirements of any particular case are known.

IRRIGATION GEOLOGICALLY CONSIDERED WITH SPECIAL REFERENCE TO THE ARTESIAN AREA OF NEW SOUTH WALES.

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[With Plates XXIII. - XXIV.]

[*Read before the Engineering Section of the Royal Society of N. S. Wales, July 20, 1903.*]

I. PHYSIOGRAPHY.—For the purposes of this paper New South Wales may be divided into three portions:—(1) The coastal plains and eastern foothills of the Main Dividing Range; (2) The Main Dividing Range; (3) The Western foothills of the Dividing Range and the Western Plains. With regard to (1) the *rainfall* over this area ranges from 24½ inches near Scone to 81 inches at Byron Bay per annum, the average of the whole area being about 43 inches per annum. This, in ordinary seasons, is ample for the requirements of pastoral, agricultural and fruit-growing industries. The question therefore of irrigation in this division is not of paramount importance except in isolated areas, where river water might be utilised for the purpose, as has been done at Mulgoa near Penrith. With reference to the possibility of the occurrence of artesian water in this division its geological structure may be summarised as follows:—From the Macpherson Range on the border of Queensland down to about 30 miles south of Grafton there is a basin-shaped extension of the Ipswich coal measures of Queensland, known as the Clarence Basin. It consists of sandstones, shales and interbeded coal seams of Triassic Age, as is proved by the occurrence in them of the fossil *Tœniopteris Daintreei*.[1] As these beds are the equivalents of

[1] Ann. Rep. Mines Dep. 1880, p. 244.

the artesian water strata to be described presently, the question as to whether or not they contain artesian water is of considerable importance. A bore has been put down with a view to testing this question to a depth of over 4,000 feet at the Racecourse, Grafton, but was finally abandoned owing to mechanical difficulties. Palæozoic rocks were not met with, and the test is therefore an incomplete one so far as the question of the presence of artesian water is concerned. It is possible, however, that the bore may have penetrated Permo-Carboniferous rocks, as is suggested by the fact that at a depth of 3,100 feet a strong supply of natural gas was met with[1]: and hitherto no authentic case of an evolution of such gas has been met with in any strata in New South Wales except those of the Permo-Carboniferous system. From the southern extremity of the Clarence Basin to Port Stephens the rocks are chiefly Carboniferous, with some Devonian, and are impervious to water.

From Port Stephens to as far south as near Ulladulla stretches the Permo-Carboniferous coal-basin, a large portion of which is overlaid by Triassic rocks. The latter are locally known as the Hawkesbury series. They have been tested in numerous places by bores, and lately by the Sydney Harbour Collieries Co's shaft at Balmain, which penetrated these rocks to a depth of 2,900 feet, and have been proved to be entirely devoid of artesian water. From Ulladulla to the Victorian border, at the Australian Alps, the strata are formed chiefly of Devonian rocks and intrusive granites, both of which are impervious to water.

We can now pass on to the Main Dividing Range [Division (2)]. This range is composed chiefly of Palæozoic and

[1] According to the foreman's report the gas became ignited from the forge, 14 feet away from the casing of the bore, and considerable difficulty was experienced in extinguishing it.

granitic rocks throughout its entire length, with the exception of the central portion, where the deep Permo-Carboniferous, basin overlaid by Triassic rocks crosses it obliquely, in a general N.N.W. direction; the portion lying to the north of this basin is known as the New England Tableland, while that to the south comprises the mountainous country extending from Gulgong to the Bathurst Plains, the Monaro Tableland, and Australian Alps. In the last mentioned, the Main Dividing Range attains its greatest elevation, about 7,328 feet at Mount Kosciusko. Its altitude elsewhere varies from about 2,000 feet up to about 4,000 feet. It has the character of a wide and deeply denuded fold range. In the southern massif the cores of the oldest axes are chiefly granites, intruding in succession Lower Silurian, Upper Silurian, Devonian and Carboniferous rocks, while the northern massif, (the New England Tableland) is formed of Carboniferous and Devonian rocks intruded by granites, porphyries, and serpentines.

The enormous amount of denudation to which this Dividing Range has been subjected may be inferred from the fact that if the great anticlines of Silurian and Devonian rock were restored over some of the granite areas like those of Bathurst, they would constitute an immense range of alpine proportions. The material removed by this prolonged erosion has partly been carried eastwards to form the Post-Carboniferous strata of the coastal area, and the Triassic, Cretaceous, and Cainozoic deposits of the Western Plains. The diversity of rock material which has thus been furnished, has resulted in the formation of soils eminently suitable for agricultural purposes, provided a sufficiency of water were available. The rainfall of the Main Dividing Range varies from 23 inches at Olinda, to 83·8 at Condong as is shown by Mr. H. C. Russell. The rocks composing this range are impervious.

(3) ***The Western foothills of the Dividing Range and Western Plains.***—A considerable portion of the western flanks of the Dividing Range from near Texas on the Queensland border to the neighbourhood of Dubbo are composed of the Triassic rocks. These consist of sandstones, shales and thin seams of coal, (a continuation of the Ipswich coal measures of Queensland). Some of the sandstones are of an extremely porous character, and these constitute the intake beds of the artesian water area. They attain altitudes of at least 1,200 feet, and have a gentle dip towards the west and north-west. Of the rainfall on the western slopes of the Dividing Range a portion is lost by evaporation, a further portion is absorbed where it falls upon the porous rocks, and the balance enters the tributaries of the Darling. As most of these tributaries cross the intake beds a considerable portion of the water which they carry soaks into the intake beds beneath their channels, so it is easy to account for the fact first pointed out by Mr. H. C. Russell, that the annual discharge of the river Darling at Bourke only amounted to 1·46% of the total rainfall within its drainage area.

Western Plains.—If a line be drawn from Nevertire through Moree to Mungundi, it approximately represents the eastern boundary of the plain country which may be termed the artesian water area. From Nevertire it is bounded by the Bogan River towards Bourke, thence in a general W.S.W. direction by a line from Bourke towards White Cliffs, and thence by an irregular line in a general westerly direction to the South Australian border. From the boundaries just described the artesian water area extends northwards and westwards into Queensland and South Australia.

The rainfall over this area varies from about 9 inches on the extreme west to about 22 inches on the east. The fall

of these plains is in a westerly to north-westerly direction at an average rate of about 2 feet per mile. With therefore this very small amount of fall in their channels the tributaries of the Darling in New South Wales where they cross the western plains are little more than canals in good seasons and a chain of waterholes in dry seasons. In times of flood, however, these rivers overflow their banks and inundate the surrounding plains for a great many miles.

II. WATER SUPPLY.—The water supply of the areas of the western foothills of the Dividing Range and of the western plains is to be obtained from (1) rivers, (2) dams, (3) wells, and (4) artesian bbres. As the subject of the use for irrigation of the river water and that of the dams is being treated of by other authors in this series of papers on irrigation, we will restrict our remarks to the occurrence of water in wells and bores.

(3) *Wells.*—Well-water has been obtained on the Western Plains chiefly from two classes of rock (*a*) Palæozoic rocks such as granites etc., and (*b*) rocks of much later age referable to various epochs in the Cainozoic Era, and largely of late Cainozoic Age. In the case of (*a*) it is only when there has been extensive decomposition of the rock to some depth that the conditions are favourable for the percolation and storage of rain water. The downward limit of the zone of saturation is in this case the upper surface of the undecomposed rock. A good example of well-water obtained from such a source is the "Medway Well," 5 miles S.W. of Byrock, sunk to a depth of 109 feet in decomposed granite. This well, even in dry seasons, yields about 5,000 gallons of water per diem, and the water rises to within 40 feet of the surface.[1] As regards (*b*), well-water has been obtained in deposits of late Cainozoic age in various parts of the Riverina in the plains bordering the Darling River and its

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[1] Ann. Rep. Mines Depart., N. S. Wales, 1885, p. 138.

tributaries even as far west as Broken Hill and Mt. Poole. Some of these wells especially those near Broken Hill have already been described by Mr. W. Anderson.[1]

The occurrence and the character of the water in this formation appears to be extremely capricious. Many wells fail to reach any supply of water at all, while of those which strike water one may yield fresh water while an adjoining well will yield brackish or salt water. The probable explanation of the latter phenomenon is that the water-bearing beds of sand or gravel in this formation are more or less irregularly distributed throughout the prevalent mass of marls and clays, and are lenticular in character, so that in the case of two contiguous wells of about the same depths and surface levels it by no means follows that they derive their supplies of water from the same stratum. These wells are mostly shallow, the depth rarely exceeding 200 feet. In no case with which we are acquainted has the age of the strata in which these wells occur been proved to be as old as Tertiary.

III. Artesian Water in Australia.—(1) *Perth Area, West Australia.*—This area consists of a narrow coastal plain extending between the western flanks of the Darling Range and the Pacific Ocean. Its width at Perth is about 15 miles, widening somewhat in a northerly direction. The greatest altitude of the intake beds where they dip off the flanks of the Darling Range must be some distance to the north of Perth, probably near the source of the Swan River, for the "rest point" of the artesian water at the Guilford Bore is at a greater altitude than the eastern edge of the coastal plain where it meets the Darling Range near Guilford. The rock underlying the surface of this coastal plain is a coarse and very porous æolian sandstone, containing fragments of marine shells of existing species. Its disinteg-

[1] Ann. Rept. Mines Depart., N. S. Wales, 1891, pp. 254 - 257.

ration has resulted in the formation of a surface covering of sand. So far as is known, the underlying strata penetrated by the bores consist of sandy shales and clays. But it appears that no continuous bed of impermeable material exists. It has been observed by one of us (E. F. Pittman) that after heavy rain on the Darling Ranges strongly flowing streams coming from the Ranges when they reach the coastal plain are very quickly absorbed by the porous rock. The deepest of these wells was about 1,800 feet, and the yield varies from 69,120 gallons per diem to 1,120,000 gallons per diem. The temperature of the water varies from 75° to 91° Fahr. The water contains from 30 to 90 grains of mineral matter, (chiefly chloride of sodium) per gallon. The rock composing Rottnest Island, 12 miles west of the coast, opposite Perth, is of the same æolian character as that of the coastal plain. There must therefore be a leakage of the artesian water into the sea.

A feature of special interest in this artesian basin is the apparent fact that there is an absence of any continuous impervious rock covering above the artesian water-bearing beds. This suggests the inference that after all an impervious stratum is not an absolutely essential part of the structure of an artesian area. The only requisites of an artesian basin may be therefore defined as those of inclined deposits of porous rock resting on an impermeable floor, outcropping at a level higher than that of the site of the bore. From the observations of the West Australian engineers it has been ascertained that 96% of the total rainfall on the catchment of the Canning River and 98% in the case of the Helena River, is lost through absorption by the decomposed granite of the Darling Range. The water so absorbed presumably goes to feed the artesian supply.

(2) *The Collie Coal-field* is a small isolated artesian area at the southern end of the Darling Range. The artesian

water occurs in coal-measures of Mesozoic Age, as has been proved from the occurrence in them of *Sagenopteris*, found by one of us (E. F. Pittman) and recognised as such by R. Etheridge, Junr. The coal is being worked near the outcrops of the seams. The basin rests on a floor of granite, and the greatest altitude of the Mesozoic rock is towards the north, the dip being in a southerly direction. Several bores have been put down to prospect for coal to depths of over 1,000 feet, (?) and these have been overflowing at the surface with artesian water for several years. As *Sagenopteris* occurs also in the Ipswich Coal-measures of Queensland, the age of which is generally considered to be Triassic, the artesian strata of the Collie Coal-field may be referred provisionally to the same age.

(3) *The Main Artesian Basin of Australia.*—The main artesian basin of Australia lies chiefly in Queensland, extending on the S.W. into South Australia, and towards the S.E. and S. into New South Wales. Commencing at the Gulf of Carpentaria and taking in the greater part of Cape York Peninsula, it trends southerly and follows approximately, as regards its eastern boundary, the outline of the adjoining coast, the distance between its eastern margin and the coast varying from about 100 to 300 miles.[1] Its southernmost development in New South Wales is in the neighbourhood of Dubbo, and as already stated, it extends

[1] This remark applies to that portion of the basin which has proved to be productive of artesian water. The fact, however, must not be lost sight of that the Triassic rocks (which usually form the storage beds of the artesian water) extend from near Toowoomba in an easterly and southerly direction to the coast, connecting with the Clarence Basin already described. All bores, however, put down in this extension east of Toowoomba, have hitherto proved unproductive. Dr. R. L. Jack, F.G.S. late Government Geologist of Queensland, is of opinion that there may be a concealed ridge of Gympie (Carboniferous) rock which may cut off at a depth the Clarence and Brisbane Trias basin from the main artesian area.

from there in a N.W. direction up the Bogan River to its junction with the Darling, and thence westward along the Darling River to near Bourke, from Bourke in W.S.W. direction to near White Cliffs, and its boundary follows an irregular course in a general westerly direction to the South Australian border. The boundary continues westerly across South Australia just north of Lake Torrens to about the 133° meridian of E. longitude. Thence it is bounded on the west by an irregular line, based at present on meagre data, following approximately this meridian northwards to its intersection with the 25th parallel of S. latitude, thence it trends in a general north-easterly direction to a point in about Long. 141° 30′ East, and about 22° S. Lat. Thence its course is in a general north-westerly direction to near the mouth of the Roper River in the Gulf of Carpentaria. The area, whose boundaries have thus been roughly outlined, is proved by the palæontological evidence to have been first chiefly a vast freshwater lake, and subsequently for the most part an inland extension of the Gulf of Carpentaria, expanding southwards into a mediterranean. The deposits of these lakes and seas subsequently uplifted constitute the present main artesian basin. The artesian-water-bearing area is thus apparently surrounded by older and impervious rocks, with the exception of its northern extremity, which meets the sea at the Gulf of Carpentaria.[1]

As regards its surface configuration, the artesian water area is for the most part a series of almost level plains and gently undulating downs. In New South Wales the surface is largely formed of plains, so nearly level that any inclination is quite imperceptible to the eye, being, as already stated, not more than about 2 feet per mile. The almost level character of these plains is due to the deposits from the flood waters of the Darling River and its tributaries.

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[1] See footnote to p. cx.

The only exceptions to the general rule as to the level configuration of the artesian area within New South Wales, are (1) the intake beds, which, as already stated, attain altitudes of at least 1,200 feet along its eastern margin, and form hilly to mountainous country along the western flanks of the main Dividing Range; and (2) the inliers of Palæozoic sediments and igneous rocks such as Mount Brown (Silurian slate), Mount Foster (Felspar-porphyry), Tibooburra (granite). These inliers formed islands in the Triassic Lakes and Cretaceous Seas during the deposition of their respective sediments; and (3) Outliers of Desert Sandstone (Upper Cretaceous). These cappings of Desert Sandstones are mostly met with in the N.W. corner of New South Wales. Over a considerable area they form low isolated hills, rising to not more than 20 or 30 feet above the general level of the surrounding country, but in places they attain to larger dimensions, up to 500 feet, as for example in the case of Mount Oxley near Bourke, Mount Poole near Milparinka and the Gray Ranges north of Tibooburra. For the most part these Desert Sandstone outliers rest on the Triassic or Cretaceous rocks of the artesian water area, but occasionally as at Mounts Oxley and Poole they repose upon Palæozoic rocks.

In Queensland a very large portion, (estimated at about 377,000 square miles, or more than half the area of Queensland) of the artesian area is composed of undulating downs, the surface rock being of Lower Cretaceous Age (the Rolling Downs Formation) which has not as yet been observed to outcrop in New South Wales unless the thin series of marls and sandy shales outcropping in the north bank of the Darling near Bourke Bridge be referable to that formation. What are considered by the Queensland geologists to be the intake beds, and termed by them the Blythesdale Braystone (the basal beds of the Lower Cretaceous System),

have been geologically surveyed by Messrs. R. L. Jack, F.G.S. and A. G. Maitland, F.G.S. According to their maps, the outcrop area of these beds is nearly 10,000 square miles. They state that the maximum altitude which these beds have been observed to attain, viz. Forrest Vale on the Maranoa River is 1,700 feet above the sea. It is necessary, however to point out that in Queensland the Older Triassic rocks (which have been proved beyond doubt to be in New South Wales the rocks from which the artesian water is obtained) occupy considerable areas to the east of the Blythesdale Braystones, and may probably attain higher altitudes than the latter.

Towards the sources of the Flinders River and its eastern tributaries Mr. Maitland[1] found that what he considered to be the Blythesdale Braystone had been eroded into narrow Cañons, several hundred feet deep as at White Mountain Creek. Mr. Rands,[2] however, as the result of an earlier examination of these beds, considered them to belong to the Desert Sandstone horizon (Upper Cretaceous). In Queensland the Desert Sandstone is much more extensively developed as regards area and thickness than it is in New South Wales. Dr. Jack states that the Desert Sandstone is sufficiently porous in places to form a storage bed for rain-water, so as to act as a feeder to the underlying intake beds. Numerous mound (mud) springs are described as occurring in the Queensland artesian area. One of the most remarkable groups is situated near Mount Browne, in 20° S. Lat. near the Flinders River. Mr. E. Palmer, M.L.A., who has described them,[3] gives the temperature of the water flowing from them as 120° Fahr.

[1] The Delimitation of the Artesian Water Area North of Hughenden, by A. G. Maitland, Assistant Geologist—Queensland Parliamentary Paper, 1898, p. 4.

[2] The Cape River Gold-field, by W. H. Rands, Brisbane.—By authority 1891, p. 11.

[3] Proc. Roy. Soc. Queensland, Vol. I., pt. 1, 1884, p. 20.

In *South Australia* the main artesian basin is represented by the same formations as those already described in the artesian areas of Queensland and New South Wales, viz., Desert Sandstone (Upper Cretaceous), Rolling Downs Formation (Lower Cretaceous) and Triassic beds. The last mentioned are typically developed at Leigh's Creek, to the south of Lake Eyre, where Triassic fossils and coal seams occur, the former similar to those of the Ipswich Coal measures of Queensland. These formations have been described by Mr. H. Y. L. Brown,[1] the Government Geologist of South Australia, the late Prof. Tate, and Mr. J. A. Watt,[2] Mr. W. Howchin, F.G.S.,[3] and Mr. R. Etheridge, Junr.[4] An account of the artesian bores and of the strata penetrated in them will be found in the official reports by Mr. J. W. Jones, the Government Conservator of Water.

The latter in a letter addressed to one of us dated July 13th, 1896, expresses the following opinion:—"In elaborating the section so as to arrive at the actual hydraulic grade line, I found, as you no doubt did, that the culminating point is in the neighbourhood of Charleville. Thence to the South end of Lake Eyre I found a fairly even grade line with a fall of about 1 ft. 9 ins. per mile. Several borings in South Australia and a number in Queensland go to show that this line departs very little from the direct line between two points; if there is any departure it is as you have shown, with the convexity uppermost. From the same culminating point to the Normanton bore, Gulf of Carpentaria, the hydraulic grade line seems almost identical with the one described. Here also the fall is about 1 ft. 9 ins. per mile."

A good description of the mound springs of the artesian area of South Australia is given by Mr. H. Y. L. Brown.[5]

[1, 2, 3, 4] Detailed references to the papers by the above authors are given in the bibliography by Mr. W. S. Dun, at the end of this paper.

[5] Aust. Assoc. Adv. Sci., Vol. I., 1887, p. 248. The Mesozoic Plains of South Australia.

"The mound springs, which are the natural indicators of artesian water beneath these plains, are found in many places near the outcrops of bed rock, between the junction of which and the Cretaceous rocks the water has, doubtless, found an easier egress. On the surface the water often forms accumulations of travertine limestone rising to heights of 40 or 50 feet, and showing in the distance across the level plains, where there is a group of springs like a low range of hills; the deposition of this limestone has, in many instances formed raised cups or basins, over the edges of which the water flows. The water of these springs contains soda, and is generally good drinking water; in some cases however, in the same group of springs, there is a great difference in the quality of the water, which in one spring may be drinkable, and in another, a few feet away, salt. As a rule these spring waters are warm, and must have a considerable temperature beneath the surface."

(4) *Details of New South Wales Artesian Area.*—Deposits overlying the storage beds. The uppermost and newest of these are more or less loose incoherent deposits which may be classed as follows:—

(i.) Flood loams and black soils.
(ii.) Red soils.
(iii.) Sandhills and claypans.
(iv.) Mound springs or mud springs.
(v.) Desert Sandstone.
(vi.) Lower Cretaceous, (Rolling Downs Formation of Queensland) shales, marls and limestone.

Flood loams and black soils.—These form the surface of the plains for a considerable distance along the course of the Darling River and its tributaries, and have been deposited from the waters of those rivers during flood time. They are composed of the material derived from the denudation of the various kinds of rocks traversed by these

rivers, and decomposed basalt probably enters largely into their composition. They are of a bluish-grey colour, and strongly plastic in character when wet, forming a serious impediment to travellers. When dry it becomes easily pulverised but forms a good road.

Black Soils.—These are more tenaceous than the flood loams, and as described elsewhere by one of us,[1] are typically developed at Moree, "where it is largely made up of decomposed basalt." Lower down the Darling it is not so dark in colour and merges into the flood loam. "With a fair amount of rain it is an extremely fertile soil—much more so than the red soil—but owing to its stiff clayey nature it is much more difficult to work." After light rainfall this soil, on account of its extreme tenacity, is even more difficult to travel over than the flood loam country.

The following is an analysis of typical flood loam by Mr. F. B. Guthrie, F.I.C.. F.C.S.:—

Locality, Collarendabri.

Nature of soil, heavy black loam.

Reaction, alkaline.

Capacity for Water, 53·6.

Mechanical Analysis—Root fibres and stones, none; coarse gravel. 0·25; fine gravel, 0·83; sand, 35·60; clay, 63·32.

Moisture, 5·69.

Volatile Matter, 6·17.

Nitrogen, ·05.

Soluble in Hydrochloric Acid—Lime, 1·00; potash, ·55; phosphoric acid, ·07.

Red Soils.—These soils are in marked contrast to the black soil on account of their lighter and more porous

[1] Mineral Resources of New South Wales, p. 466.

nature as well as their colour. The colour is of a dull reddish-grey due to peroxide of iron, and it is probable that they have resulted from the disintegration of ferruginous beds in the Desert Sandstone. They occupy irregular shaped isolated areas, and their level is generally slightly higher than that of the surrounding black soil or flood loam deposits. In the present state of our knowledge it would be unsafe to venture an opinion as to the thickness of this red soil formation, and its relation to the underlying strata, (newer than the Cretaceous), which in many places yield supplies of brackish well water. The following is an analysis by Mr. F. B. Guthrie, F.I.C., F.C.S., of this red soil:

Locality, Pera Bore.

Nature of soil, light sandy loam, red.

Reaction, very slight alkaline.

Capacity for Water, 28·3.

Mechanical Analysis—Root fibres, 0·12; stones, none; coarse gravel, 0·12; fine gravel, 0·91; sand, 79·04; clay, 19·81.

Moisture, 3·21.

Volatile Matter, 3·94.

Nitrogen, ·03.

Soluble in Hydrochloric Acid—Lime, ·13; potash, ·36; phosphoric acid, ·25.

Sandhills and Claypans.—What is known as sandhills and claypan country forms one of the most remarkable features of the north-western portion of the New South Wales artesian area. Typical examples of this formation are particularly noticeable between the Clifton Bore, and the town of Milparinka, on the road between the latter place and Wanaaring. They consist of a series of hills of blown sand alternating with more or less regularly shaped depressions (claypans) the floors of which are composed of clayey material. These have already been described by one of

the authors,[1] and the following extracts will convey an idea as to their general character:—"The sandhills which vary from small mounds to hills 50 feet in height are formed of blown sand. . . . There can be no doubt that the sand of which these hills are formed is due to the disintegration in Post Tertiary times of the Upper Cretaceous or Desert Sandstones. The claypans, which are invariably met with in proximity to the sandhills, are shallow, flat bottomed depressions; they vary in depth from a few inches to three feet, and their floors consist of a thin bed of fine clay, upon which the water lies for a considerable time after rain. They are often quite circular in shape, while, in other instances they form long channels of regular width. . . . It seems probable that they have been formed by the whirlwinds (the *Burramugga* of the aborigines) which are of very common occurrence in this country. Some of these whirlwinds remain stationary for a considerable time (forming columns of whirling sand, sometimes a quarter of a mile high), which suggests the formation of the circular depressions—while a travelling whirlwind, such as is frequently met with, might be expected to sweep up the sand in such a manner as to form one of the long narrow channels. The depressions having thus been formed, subsequent rains would carry into them, in a state of suspension, fine clay washed out of the surrounding sandy soil. When the water was afterwards evaporated by the heat of the sun, or had sunk into the floor of the depression, a coating of clay would be left, and frequent repetitions of this process would leave a fairly thick bed of impervious clay."

Mound Springs or Mud Springs.—These have been described by one of the authors in the work already referred

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[1] "The Mineral Resources of New South Wales," by E. F. Pittman, 1901, pp. 465–466.

to,[1] and references to descriptions by various authors will be found in a paper by another of the authors.[2] The mound or mud springs are literally springs of liquid mud which by overflowing at the surface have gradually built up conical mounds, which in New South Wales are from a few feet to 50 feet or more in diameter, and up to about 15 feet in height. (In South Australia, however, Mr. H. Y. L. Brown has described some mound springs which attain a maximum height of about 50 feet). The material of the mounds is formed of yellowish clay whitened in places by calcareous incrustations. A noteworthy feature is the occurrence in this clay of waterworn pebbles of quartz. [In Queensland in the mound springs described by Mr. E. Palmer (*op. cit.*, p. 20) on the Lower Flinders River, the water is stated to evolve innumerable bubbles of carbonic acid]. As regards their distribution, an important characteristic is the fact that they usually occur in proximity to the junction between the older rocks and those of the artesian water-bearing series; in other words they are found adjacent to the edges of the basin or to the edges of the inliers of older rocks which at one time formed islands in the Triassic lake and Cretaceous seas. The experience has been that bores put down for artesian water near these mud springs have invariably yielded a much smaller flow than those situated at greater distances from the margin of the basin. It may also be mentioned that when bores have been sunk near mound springs, and have struck supplies of artesian water, as the result of the diminution of the pressure caused by the bore the water has ceased to flow from the adjoining mound springs. This has notably been the case at the Officer Brothers' Bores at Kilara. In cases where observations have been made as to the temperature of the liquid

[1] The Mineral Resources of N. S. Wales, by E. F. Pittman, pp. 466 – 467.
[2] Journ. Roy. Soc. N.S.W.

mud flowing from the mound springs, as in Queensland, records as high as from 120° Fahr. have been obtained, as for instance at Mount Browne on the Lower Flinders. As the mean surface temperature of that locality is considerably lower than this, it is obvious that the liquid mud in such cases must come from some depth. This consideration taken in conjunction with the fact already stated that flow from artesian bores dries the mud springs in the vicinity proves that the source of the springs is to be found in the artesian wells water-bearing strata. The mud springs are in fact natural artesian wells, where the water under pressure from the storage beds below forces its way to the surface through the overlying clayey beds, where they are thinnest, and therefore offer least resistance. As might be expected, these conditions are found near the margins of the basin in proximity to the older rocks, for there the upper beds of the artesian series which are usually impervious clays become more sandy and therefore more porous, in accordance with the well known rule that sediments become coarser the nearer they are to the parent rocks from which they have been derived.

Desert Sandstone.—This formation, to which reference has already been made, is of Upper Cretaceous age, and extends as far south as Bidura near Balranald. Northwards it extends into Queensland, westwards into South Australia, and south-eastwards it extends up to or even considerably beyond the limits of the artesian basin. It does not follow therefore, that the formations underlying Desert Sandstone areas always belong to the artesian series, as in many cases the Desert Sandstone rests immediately upon the older rocks. Owing to the great denudation which this formation has undergone, it does not extend continuously over the areas just described, but occurs as isolated and generally low hills or ranges. These in New

South Wales occasionally attain a height above the surrounding plains of 500 feet, and a maximum altitude of about 900 feet above the sea, as at Mount Poole in the Grey Ranges. The higher hills frequently exhibit steep escarpments, the beds being horizontal or nearly so, and having vertical joints.[1] The beds consist of conglomerates, sandstones, and porcellanites and a very fine grained white siliceous rock having much the appearance of kaolin in general character. Occasionally the sandstones and porcellanites are very ferruginous, and it is thought that these beds have contributed largely to the material of which the red soils are formed. The porcellanized portions are impervious to water, but some of the sandstones are very porous, and it is conceivable that, as pointed out by Dr. Jack, where they overlie the intake beds they may act as feeders to the artesian supply.

Rolling Downs Formation.—As already stated, this formation, though proved by the artesian bores to have an extensive development in New South Wales, does not outcrop at the surface with the exception perhaps of the marly clays, already mentioned, seen in the north bank of the Darling at the bridge above Bourke. At about 20 miles west of Depôt Glen near Mount Poole, the spoil heaps of some shallow wells show marine fossils of Lower Cretaceous age, proving that that formation comes very close to the surface at this point.

Owing to the fact that most of the artesian bores in New South Wales are made with percussion drills, the material penetrated is so ground up that it is very difficult to decide at what depth the Cretaceous beds and the Trias respectively begin. In two notable cases, however, viz.,

[1] A description of this formation has already been given by one of the authors.—The Mineral Resources of N. S. Wales, by Edward F. Pittman. pp. 464–465.

at Bulyeroi (60 miles west by south from Moree) and at Wallon (20 miles north by west from Moree) the characteristic Lower Cretaceous fossils were obtained in bores through the use of the Calyx drill, which has the advantage of bringing up a solid core. The evidence conveyed by these fossils is of particular interest as bearing upon the disputed question as to whether the Lower Cretaceous Sandstones (Blythesdale Braystone of Dr. Jack) or the underlying sandstones of Triassic age form the true intake beds of the artesian area.

At Bulyeroi the Lower Cretaceous rocks were penetrated to a depth of 520 feet, and at 175 feet from the surface a very small supply of sub-artesian water was met with. Below 520 feet Triassic rocks with characteristic plant remains were struck, and in them at a depth of 1,386 feet from the surface the first supply of artesian water was found, equal to 6,000 gallons a day. At a depth of 2,370 feet the flow had increased to 1,750,000 gallons per day.

At Wallon Bore the Lower Cretaceous rocks extended to a depth of 1,500 feet from the surface, and they yielded characteristic marine fossils such as *Corimya*, *Maccoyella* and *Pinna*. No water was obtained in these beds. At 1,630 feet from the surface the characteristic Triassic[1] fossil *Tæniopteris Daintreei* was recognised, and a coal seam 15 inches thick was intersected at a depth of 1,650 feet. The first artesian water flowing at the rate of 400 gallons per day was not met with until the bore had reached a

[1] NOTE—Wherever the term Trias or Triassic is applied, in this paper, to rocks other than those of the Hawkesbury Series, it must be understood that the use of these terms is only provisional. It is quite possible that their age may eventually prove to be Jurassic, like that of the Victorian Series, and that of the Clarence Series of New South Wales as originally suggested by the late C. S. Wilkinson.—*Min. Products N. S. Wales*, 1882, p. 55.

eet, that is well into the Triassic Coal- the boring progressed below this depth, the continued to increase until it reached its 500,000 gallons per day, at a depth of 3,560 feet.

evidence is conclusive, and proves that in New South s, at any rate, the Triassic sandstones, and not the thesdale Braystone form the storage beds of the artesian area. Moreover it is doubtful whether the Blythesdale Braystone extends into New South Wales territory, as nothing resembling it was recognised at the base of the Cretaceous rocks in either the Bulyeroi or Wallon bores. The respective levels of the base of the Cretaceous formation in the Bulyeroi and Wallon bores shows that the bed of the Cretaceous Sea dipped rapidly northwards from Moree into Queensland. It is probable therefore that the Blythesdale Braystone of Queensland may have thinned out against a sloping surface of Triassic rock in the direction of the New South Wales border. It may therefore act as a feeder to the underlying rocks of Triassic age. It is obvious from the facts adduced that the Lower Cretaceous rocks of New South Wales are essentially impervious, and do not form any important part of the storage beds of the artesian area. Lithologically they consist of marly and sandy shales and marine molluscan limestones. In Queensland and South Australia the sandy shales and limestones of this formation contain abundant foraminifera, with occasional infusoria and diatoms, but only a few microzoa of this kind have been observed in rocks of this age in New South Wales.[1] Although there may be local evidence of thinning out of the basal beds of the Lower Cretaceous against the Triassic strata in New South Wales, no distinct evidence has been obtained in New South Wales as to there

[1] A Census of the Fossil Foraminifera of Australia, *Proc. Austr. Assoc. Adv. Sci.* for 1893 [1894], v., pp. 348 – 373.

being any unconformity between the two formations. It should be mentioned that the Queensland Geologists state that they have observed such unconformity in parts of their territory, but their descriptions leave it an open question as to how far the phenomena recorded may be due to contemporaneous erosion rather than to unconformity.

The Intake Beds.—The intake beds consist of porous freshwater sandstones of the Triassic series. These beds extend into New South Wales from Queensland, and are first seen on the Dumaresq (Sovereign) River at a point 15 miles west of the township of Texas. The eastern margin of the intake beds in New South Wales can be traced thence in a S.S.W. direction as far as Dubbo. As already stated, they form part of the western flanks of the Dividing Range. They have an average width of probably 60 miles. They dip gently westwards, and it is believed that they are continuous under the Cretaceous rocks for the whole width at least of the portion of the artesian area which lies in this State. For example, at Salisbury Downs, west of Wanaaring, the characteristic Triassic fossil *Tæniopteris Daintreei*, was obtained from near the bottom of the bore. This point is about 400 miles west of the eastern boundary of the intake beds. The series consists of shales, sandstones and coal seams, and their aggregate thickness in places, as for example at the Wallon and Bulyeroi Bores is at least 2,000 feet, but of this thickness only a small portion is made up of the porous beds which occur at intervals in the series. In places the intake beds are of a very porous character, as for example near Wallangra, and between Yetman and Texas. At the last named area the sandstones have undergone considerable disintegration giving rise to a thick superficial covering of sand, about 20 miles in width. As regards altitude the intake beds attain an elevation of about 1,200 feet above sea level between Texas and Yetman.

At Black Jack, and Curlewis near Gunnedah, their height above sea level is respectively about 1,670 feet and 1,730 feet, and at Narrabri and Rocky Creek their height above sea level is about 2,250 feet.

Thickness of porous beds as proved in bores.—At the Bulyeroi Bore (about 60 miles S.W. of Moree) artesian water was first struck at a depth of 1,386 feet in a bed of porous sandstone 160 feet thick. A fresh supply was struck at 1,896½ feet, and from here to the depth at which bed rock was struck, viz, 2,370 feet, the flow continued to increase, amounting to a total of 1,750,000 gallons per diem. Of the strata between the levels of 1,896½ feet and 2,370 feet only about 30 feet were shales, the remainder being sandstones with a thin band of conglomerate. In this case the lower division of the porous beds has therefore a thickness of about 444 feet, and if to this be added the 160 feet of porous rock in the upper division the total thickness of porous beds belonging to the Triassic formation, at this bore amounts to about 600 feet. The Bulyeroi Bore was bottomed on bed rock.

At *Woolabra Bore*, between Narrabri and Moree, the first water bearing strata were struck at 930 feet, and proved to be about 35 feet thick: the next were struck at 1,125 feet and proved to be about 60 feet thick; the next at 1,209 feet, thickness about 180 feet, which makes a total thickness of porous strata in this bore of 285 feet. Bore bottomed on hard rock.

At the *Tenandra Bore*, yielding 1,200,000 gallons of water per diem, the first supply of artesian water was struck at 484 feet, and continued to increase down to a depth of 815 feet. As the intervening strata are described as sandstones and shales, and the shales are of course impervious, the porous beds must be considerably less in thickness than the strata between these levels, that is much less than 331 feet. Bore bottomed on bed rock.

At the *Warren Bore* the total flow is approximately 1,000,000 gallons per diem. The first flow was struck at 463 feet and amounted to 500,000 gallons per diem, being derived from a bed of sandstone and conglomerate 12 feet thick. At 601 feet the flow was increased from a bed of sandstone 15 feet thick. At 680 feet a further increase in the flow was obtained from a bed of sandstone 20 feet thick, while at 720 feet another bed of sandstone 95 feet thick was penetrated in which the flow reached a total of 1,000,000 gallons per diem. The intervening strata between the water-bearing horizons consisted of shales. Total 142 feet of porous strata. Bore bottomed on bed rock.

Carinda Bore between Walgett and Warren, 1,000,000 gallons per diem. First flow obtained at 1,290 feet from 15 feet bed of sandstone, at 1,550 feet a further flow from a 10 feet thick sandstone. At 1,626 feet a 10 feet bed of porous sandstone, and 1,660 feet a 7 feet bed. Bore discontinued in shales (minimum thickness of porous beds 42 feet). Not bottomed on bed rock.

Kenmore Bore, north of Yantabulla, 2,050,000 gallons. First flow 1,267 feet from sandstone bed 2½ feet thick. Second flow 1,343 to 1,500 feet = 157 feet. Total thickness of porous beds about 160 feet. Bottom hard rock.

Mooramina Bore, between Narren Lake and Walgett, 1,069,920 gallons. At 1,740 feet from sandstone 53 feet thick; at 1,956 feet increased flow from sandstone 62 feet thick; and at 2,110 feet another flow from stratum called "coarse sand drift," 17 feet thick; and at 2,250 feet, flow was increased, and at 2,271 feet 9 inches flow attained its maximum, but water stratum not cut through. Not bottomed. Therefore minimum of porous beds 154 feet.

Tulloona Bore, east of Dolgelly, north of Moree. First flow at 2,910 feet from bed of sandstone, 22 feet thick; second flow at 3,012 feet ? 20 feet sandstone; third flow

between 3,058 and 3,500 feet, chiefly sandstone and shaly sandstones, = total of about 584 feet (say 600 feet) of porous beds.

Wilby-Wilby Bore, north of Narren Lake, 1,114,800 gallons. First flow 1,750 feet from sandstone 36 feet thick; second flow 1,940 feet from sand 10 feet thick; third flow 2,160 feet from sandstone 20 feet thick. Bore was not carried to bed rock, minimum thickness of porous beds 66 feet. Summary of ascertained thickness of porous beds:—

Bulyeroi	600 feet	
Woolabra	285 ,,	
Tenandra	? 150 ,,	(about)
Warren	142 ,,	
Carinda	42 ,,	$+ x$
Kenmore	160 ,,	
Mooramina	154 ,,	
Wilby-Wilby	66 ,,	$+ x$
Tulloona	584 ,,	(about)

For the purposes of the calculation at the conclusion of this paper the mean thickness of the porous strata underlying the artesian area of New South Wales has been estimated at 300 feet.

The impervious rocks underlying the storage beds.—A knowledge of these can be obtained from studying the chips of rock resulting from the boring by percussion drills recovered from such bores as have reached bed rock, and in part their nature may be inferred from the character of the rocks forming the rim of the artesian area. As regards the latter, the eastern rim of the basin, where it touches the Queensland border consists of granite. Further south it is formed chiefly of Carboniferous rocks to near Narrabri. Thence to the Warrumbungle mountains the bed rock is partly Permo-Carboniferous with occasional granite areas and older sedimentary rocks. Thence as far as

Dubbo and for about 12 miles in a south-westerly direction the bed rocks are Silurian and Devonian slates, limestones and quartzites, with granite. The granite is followed by a synclinal trough of Devonian sandstones which extends southwards past Bogan Gate, the width of the trough being about 20 miles. The rocks hitherto described, with the exception of this Devonian trough, and the Permo-Carboniferous strata of Ballimore to be described later, are all impervious.

The sandstones, however of the Devonian are, at any rate at the surface, of a porous character, and in view of their occupying a synclinal fold which abuts against and probably underlies the southermost portion of the artesian area, there seems to be a possibility of their also being water bearing. With a view to testing this question, the Government are putting down a bore on Gennaren Leasehold area, between Peak Hill and Dandaloo. From the north end of this Devonian Syncline the bed rock outcrops near Girilambone, and to the east of Byrock and at Brewarrina, and consists largely of micaceous slates and schists with occasional patches of granite. From Brewarrina to near Wilcannia the bed rock does not outcrop near the edge of the basin, but the evidence supplied by some of the bores, such as that at the Trucking Yard at Bourke show that it is formed of slaty rock. At Wilcannia Devonian quartzites outcrop and extend to the Barrier Ranges where they are succeeded by still other rocks, probably Silurian.

Reference to the map exhibited shows that the artesian wells are not plentifully distributed over that part of the artesian area which lies between the Culgoa River on the east and the Paroo River on the west. A very large proportion of the bores put down by the pastoralists as distinct from those put down by Government lie within the above

area. By far the greater number of the bores in this area have succeeded in striking artesian water. The failures have proved most numerous in the southern portion where it approaches the Darling River.

The deepest part of the artesian basin and that which also yields the largest flows of water lies within the area between Brewarrina, Dubbo, and Yetman.[1] Hitherto the number of bores in this area are far fewer than in the one just described. The most southerly of the flowing bores are those of Warren and Gilgandra.

As regards surface levels these have been determined, in most cases, only very approximately. At Moree the level of the plain is 680 feet, at Bourke the level of the plain is 350 feet above the sea, so that there is a surface fall from Moree to Bourke in a distance of about 240 miles, and in a direction about west by south, of about 330 feet. As regards the surface levels of the western part of the artesian area, the altitude of Mount Poole above the sea is about 900 feet, as determined by aneroid; and the top of Mount Poole is about 500 feet above that of the surrounding plains. The level of the plains in this neighbourhood is consequently about 400 feet above the sea. The surface fall therefore from Mount Poole easterly to Bourke, a distance of 250 miles is only about 50 feet.

Temperature of water flowing from New South Wales artesian wells.—The average temperature of the water flowing from 48 Government bores is 107° 81 Fahr., and the average depth 1,795 feet. If the mean surface temperature be assumed to be 68° Fahr., there is an average increase of temperature due to depth of 1° for every 44 feet.

Chemical composition.—The following may be quoted as examples of the composition of the artesian water respec-

[1] See the Mineral Resources of New South Wales by Edward F. Pittman, section opposite p. 461.

tively from the east side of the basin, the central portions, and the west:

Locality.	Total solid matter in grains per gallon.	$NaCO_3$	K_2CO_3	$CaCO_3$	$MgCO_3$
1. Moree	49·78	39·26	1·10	·64	·29
2. Euroka (Walgett) ...	75·21	56·49	...	·25	trace
3. Kelly's Camp... ...	35·08	16·87	5·67	·69	trace
4. Wanaaring	50·63	35·79	1·28	1·30	·19

Locality—*continued.*	NaCl	K_2SO_4	Fe_2O_3 and Al_2O_3	SiO_2	Organic Matter.
1. Moree	7·03	...	trace	1·46	trace
2. Euroka (Walgett) ...	15·32	1·28	...	..	...
3. Kelly's Camp... ...	7·91	...	·20	1·32	2·44
4. Wanaaring	10·39	...	...	1·68	trace

It is noticeable that the chief mineral constituent of the water in nearly all New South Wales artesian water is carbonate of soda, the next most important being chloride of sodium. The total solid matter varies from 31·50 to 396·87 grains per gallon; the latter is however exceptionally high, and the average according to sixty-five analyses is about 85 grains per gallon. It has been observed that the proportion of mineral matter is usually higher in those bores in which a sub-artesian supply only has been obtained, and the same rule appears to apply to bores which have a very limited flow.

Gases in bores.—A distinguishing feature of the artesian water obtained from bores in New South Wales is a strong odour of sulphuretted hydrogen, which is very noticeable in the water when it first issues from the bores, but which speedily passes off after exposure to the atmosphere. Mr. W. M. Hamlet, Government Analyst, however, states that after visiting a number of the bores, and subjecting the water to careful tests, he was unable to obtain any reaction for that gas or for free sulphuric acid. With the exception of the Ballimore Bore near Dubbo, which yields a flow of

carbonated water, none of the artesian bores in this State are known to evolve free carbon dioxide. We have therefore, at present, no evidence to show that gas pressure plays a part in the rise of the artesian water of New South Wales.

Variation in amount of flow from artesian bores.—In several instances, notably at Pera Bore, near Bourke, and also at the Coonamble Bore, a marked diminution of flow has been observed of late years. The falling off in the yield in these two instances was brought under notice by reason of the fact that the water is utilised for irrigation and other purposes, and it is more than probable that at many other bores where re-measurements of the flows have not been recently made, a corresponding decrease in the flow has occurred. At Pera, the first bore put down yielded 610,000 gallons a day when just completed, but in the year 1900 the yield was found to have diminished to 300,000 gallons per day. A second bore was then put down about a mile from the first, but the flow from it did not exceed 250,000 gallons per day.

A feasible explanation of this falling off in the yield is that the protracted drought through which we have just passed has materially lessened the amount of water absorbed by the intake beds. We are unable to state with any degree of accuracy how long the water would take to travel down the porous beds from their intake to a point several hundred miles westward, but inasmuch as the drought referred to lasted for more than five years, it appears reasonable to assume that it was of sufficient length to account for the reduced intake making itself felt at Pera.

In addition to the long period variations in the flow from the artesian wells just referred to, the artesian water has been observed at one locality (Urisino Station, Wanaaring to Milparinka Road), to be subject to some very remark-

able oscillations. At this station there is a well 30 feet deep, from the bottom of which a bore has been put down to a total depth from the surface of 1,680 feet. The water rises in the well to a mean height of about 17 feet below the surface. The temperature of the water has been recorded by the station manager as 120° Fahr. The water rises and falls in the well to a varying extent (between 3 and 4 feet), and the periods of its oscillation are also variable, the period between two successive ebbs or flows ranging from about 9 hours to 17½ hours. Through the kindness of Mr. H. C. Russell, a tide recorder was placed in the well, and was put in charge of the caretaker of the nearest Government well. Owing, however, to the fact that he had to travel 12 miles every time he attended to the tide recorder, the observations were not as reliable as could have been desired, and as he left the district shortly afterwards, further observations were abandoned on account of the impossibility of getting any one to attend to the gauge.

The accompanying table and diagram No. 1 *Plate 23* represents the oscillations of the water as recorded by the tidal gauge for a period from 28th February to the 18th of May 1897. During this period the variation in time between successive ebbs and flows was from about 9 to 14 hours, while the rise and fall of the water varied from about 3 ft.

Observer.	Time between successive "high tides."		Rise and fall of water.	
	Maximum	Minimum.	Maximum	Minimum.
	hours.	hours.	′ ″	′ ″
E. F. Pittman, 6th to 12th Nov., 1894. (No. 2 Diagram, Pl. 24, lower right hand corner.)	18	16½	1 11	1 6
Caretaker, 29th May to 2nd June, 1896. (No. 2 Diagram, Pl. 24, lower left hand corner.)	12	8	3 2	2 9
Caretaker, Feb. 28th to May 18th, 1897. No. 1 Diagram, Pl. 23, large sheet.)	14½	8¼	3 11	3 2

3 ins. to 3 ft. 9 ins. Different results were obtained by observations taken during two short periods, viz. from November 6th to November 12th, 1894, and from May 30th to June 3rd, 1896. These are shown on diagram No. 2, *Plate 24*, which also represents the position which the bore occupies with regard to the well.

In the first named period the successive ebbs and flows occurred at intervals of about 17½ hours, whereas in the latter the interval was about 10 hours. Minor oscillations may be noticed at the top of the curve obtained in the last named period, but the explanation is not clear, and it is possible that they may have been caused accidentally by some temporary defect in the tide recorder. Further investigation is needed before any reasonable explanation can be offered of this remarkable and interesting phenomenon viz., the rise and fall of the sub-artesian water. The chief obstacle to further investigation is the inaccessible situation of the bore, and the absence of camping facilities at the spot. This occurrence at Urisino raises the question as to whether a similar phenomenon may not obtain at all the artesian bores, and this could perhaps be ascertained by attaching pressure gauges to their outlets, and observing whether the pressure varies from time to time.

Occurrence of artesian water in rocks of Permo-Carboniferous Age.—The only locality in New South Wales where artesian water has been proved to occur in strata of the above age is at Ballimore on the Talbragar River, 20 miles north-east of Dubbo. A bore was put down to search for coal at this locality in 1886, and according to the report by Mr. W. H. J. Slee, F.G.S., at a depth of 540 feet the drill passed through a seam of coal 5 feet 2 inches thick, and while the boring was being continued to the second seam, which occurs 5 feet below the first, a supply of artesian water was struck, equal to 1,000 gallons per

hour, which rose in the vertical pipes 30 feet above the surface. The water contained a considerable quantity of free carbonic anhydride, which distinguishes it from the ordinary artesian bore, and points to the probability of the flow being caused by the pressure of the gas. The following analysis of the Ballimore water was made by Mr. J. C. H. Mingaye, F.I.C., F.C.S. :—

Bicarbonate of sodium	183·10	grains per gallon
,, potassium ...	12·83	,, ,,
,, lithium	·05	,, ,,
,, calcium	11·38	,, ,,
,, magnesium ...	9·36	,, ,,
,, strontium ...	trace	,, ,,
,, iron	·70	,, ,,
Chloride of sodium	6·92	,, ,,
Alumina	trace	,, ,,
Silica	·28	,, ,,
Total solid matter ...	224·62	,, ,,
Free ammonia	0·052	parts per 100,000
Organic or albuminoid ammonia	·003	,, ,,

Specific gravity of water at 65° F. 1·00359.

Trace of phosphoric acid present. The water has a pleasant taste and is highly charged with carbonic acid.

According to the report[1] by Mr. W. Anderson, F.G.S., (at that time Geological Surveyor in the Department of Mines, New South Wales, now Government Geologist of Natal,) the Triassic Hawkesbury Sandstone which there forms a thin capping on the hills is underlain by a coal measure series containing rootlets and leaflets of *Glossopteris*. The age of the artesian water bearing beds at Ballimore is therefore proved to be Permo-Carboniferous.

[1] Ann. Rep. Mines Dept., 1888, pp. 184–187.

IV. Origin and Flow of Artesian Water.—In recapitulation of the conditions under which artesian water occurs in New South Wales it may be stated that the following appear to be the most noticeable facts:—(1) A wide belt of very porous sandstone outcrops on the east side of the artesian area between the Queensland border and the town of Dubbo. These sandstone beds occur at very much higher altitudes than the western plains on which the artesian bores are situated. They have a slight westerly dip, and extend continuously under the plains for a distance of at least 400 miles in a westerly direction. This has been proved by their intersection at varying depths in all the bores, and by the occurrence of the characteristic fossil *Tæniopteris Daintreei* from near the bottom of the bore on Salisbury Downs Station, west of the Paroo River. (2) The outcrops of these porous beds receive a mean annual rainfall of 25 inches, and owing to their extreme porosity there can be little doubt that a very considerable proportion of the rainfall is absorbed by them, and percolates through them in the direction of their dip under the western plains. Six of the main tributaries of the Darling River, the Dumaresq (Sovereign), the Macintyre, Gwydir, Namoi, Castlereagh, and Macquarie, rise in the ranges to the east of the porous intake beds, and have eroded their channels through the latter. Some of these rivers, notably the Macquarie, never reach the Darling except during times of flood. There can be no doubt that this is due to the fact that a considerable proportion of their water is absorbed by the intake beds, over which they flow, and serves to augment the supply of the artesian area. Mr. H. C. Russell has pointed out that of the rain which falls within the catchment of the Darling only $1\frac{1}{2}\%$ passes Bourke in the river channel. The balance can be accounted for only by evaporation and absorption. There can be little doubt

that a considerable proportion of it is to be accounted for in the latter way.

These facts point to the conclusion that the rise of the water in the artesian bores of the western plains must be due to either hydrostatic or hydraulic pressure. We believe the pressure to be hydraulic rather than hydrostatic for the following reasons :—(1) If the pressure were hydrostatic, that is if there were no outlet for the water which accumulates in the porous beds, it stands to reason that it would ultimately become saturated with the mineral matter dissolved from the rocks through which it had percolated. As a matter of fact, however, the water in the artesian wells contains, as already stated, only a small amount of mineral matter in solution, and this fact must be regarded as evidence that the water has a circulation. There are valleys in the artesian area which could intersect the porous beds at a sufficient depth to allow of this circulation; and the amount of water which escapes from the mound springs within this area is so small that it may be regarded as negligible. The only other possible way in which circulation could be maintained would be by leakage to the ocean. That there is leakage to the ocean is borne out by the fact that the porous beds have been found to extend along the eastern and south-eastern shore of the Gulf of Carpentaria. It may further be stated that if there were no circulation of water in the artesian beds, that is if the water were hydrostatic instead of hydraulic, it appears to us that the beds must long ago have become saturated with water, with the result that numerous strong springs would be observable in the valleys intersecting the intake beds. No such springs, however are known to exist.

V. Estimated Annual Inflow of Water into the Artesian Beds of New South Wales.—The area of the intake beds has not yet been accurately surveyed, but it

may be provisionally stated to be approximately 18,000 square miles. As the mean annual rainfall on this area is 25 inches, it follows that 1,045,000,000 cubic feet of water falls upon it annually. If it be assumed that only 20% of this rainfall is absorbed by the intake beds (and we consider that this is a low estimate), a volume of water equal to 3,580,273,972 gallons per day would percolate through the porous beds under the western plains. This volume is more than 27½ times the amount which at present flows from the 284 bores which have been put down.

VI. The Storage Capacity of the Porous Beds.—The area of country underlain by water bearing beds in New South Wales is 83,000 square miles. The thickness of the water bearing beds, intersected in the bores varies from 600 feet on the east near the intake to 100–200 feet on the western side of the area. There are therefore about 471 cubic miles of water bearing sandstones in the artesian area of New South Wales, and assuming that this sandstone will absorb 12% of water, these 471 cubic miles of porous stone will hold 56½ cubic miles of water.[1] As the six principal tributaries of the Darling have eroded their channels through the intake beds there must be a great leakage of their water into the porous beds of the artesian area, and this is no doubt the reason why such important rivers as the Macquarie never reach the Darling except in flood time. Hence the estimate already given of the

[1] Experiments with a sample of Blythesdale Braystone, taken by one of us (E. F. Pittman) from 8 miles north of Roma, Queensland, made by Mr. F. B. Guthrie, F.C.S., F.I.C., at the Agricultural Laboratory of the Department of Mines and Agriculture, show that this rock will absorb quite 12½% of water, while a sample of the Triassic sandstone from near Yetman was found to be capable of absorbing 25%. As the bulk of the artesian water of New South Wales is stored in Triassic rocks, and the estimates quoted above are based on the porosity of the Cretaceous sandstone, which is less than that of the Triassic, the above estimate may be taken as a minimum.

quantity of water absorbed by the intake beds from rain falling upon them must be increased considerably by reason of the water flowing down these rivers from areas to the east of the intake beds. As however, this increase is an unknown quantity, it has been omitted from the calculation, and we would accordingly emphasize the fact that our estimate of the amount of water annually absorbed is probably a minimum one.

With reference to our statement that the water annually absorbed by the intake beds exceeds by 27½ times the amount which is being drawn from the existing bores, it must not be inferred that it would be possible to increase the flow from bores to that extent. If our view as to the pressure being hydraulic be correct, it is obvious that there must be a point beyond which the bores could not be multiplied without so lowering the hydraulic grade by diminishing the frictional resistance to the movement of the water, as to convert artesian into sub-artesian wells.

VII. Possible Uses of Artesian Water.—With regard to the possibility of increasing the range of usefulness of artesian water it may be mentioned that in addition to its employment for the use of stock and for irrigation, there are many other purposes to which it can be applied. For example, advantage is taken of the high temperature of the water, and its curative properties, to use it for hot baths, as is the practice at Moree, Charleville, etc. It can be utilised as a source of power for electric lighting, shearing, driving sawmills and other machinery.

The area which can be irrigated from the bores is obviously a consideration of vast importance. According to the usual estimates it is possible to irrigate one square mile of land by means of a bore yielding one million gallons of water per day. The present outflow of our bores being 136 million gallons per day, it would be possible from this

source to irrigate 136 square miles. According to the approximate data which we have already assumed, it should be possible to so increase the flow by multiplying the bores as to suffice for the irrigation of a vastly larger area; but the problem as to the extent to which the outflow can be increased without converting the artesian into sub-artesian wells, is one which can only be satisfactorily solved by a hydraulic engineer, who is at the same time an able physicist and mathematician, and one provided with ample opportunities for investigation. It is very desirable that such an investigation should be undertaken with as little delay as possible.

VIII. Suggestions for Obtaining More Accurate Knowledge of Our Artesian Water Supply.—(1) We would recommend the appointment of a thoroughly competent hydraulician with the qualifications just mentioned, to study accurately the flow of the different bores, its variation at stated intervals, and of the peculiar phenomena observed at the Urisino Bore, as well as the pressure and the altitudes of the bores. It is quite possible that subsequent investigation will show that many others, if not all, the bores are subject to the same tidal movements which characterise Urisino. In case of bores in which the flow is artesian instead of sub-artesian as at Urisino, this can probably be determined by periodic variations in pressure. (2) We would recommend that accurate gaugings be made of the flow of rivers (*a*) just above where they reach the edge of the intake beds, and (*b*) just where they leave the intake beds. The difference in the amounts, at these two respective positions will give the approximate amount of leakage of river water into the porous (intake) beds, and will so afford data for estimating what quantity of water derived from this source, must be added to that due directly to rainfall on the porous beds, in order to estimate the total

amount of water which annually enters the artesian area through the porous beds. (3) Lastly, we would recommend that an accurate geological survey be made of the intake beds within the State, with the object of ascertaining the area within which the rainfall is absorbed by the porous beds.

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numerous brine springs; the most remarkable of this class perhaps, being the Salt Well at Kissengen, in Bavaria, from which the water rises from a depth of 1,878 feet to a height of 58 feet above the curb. It is alleged that this is due rather to carbonic acid gas generated at the junction of the limestone and gypsum formation than to hydrostatic pressure.

In 1866 the Municipality of Paris let a contract for an artesian well at Passy to the German engineer, Kind, who commenced operations with a hole of nearly 4 feet diameter, using a "trepan" or bit of special construction. A depth of over 1,700 feet was reached, when the upper portion of the boring collapsed filling up the hole. Operations were resumed, and the bore was contracted to a diameter 2 feet 4 inches, and at a depth of 1,904 feet, a supply, which quickly increased to 5,500,000 gallons per diem, was struck; this enormous supply is thrown to a height of 54 feet above the surface. The cost of this well, which was commenced in 1855, and completed in 1861, amounted to nearly £40,000. In addition, two other wells are worthy of mention:—that at La Chappelle, 5 feet 7 inches in diameter, abandoned at a depth of 1,745 feet; and that at the Butte aux Cailles, 6 feet in diameter, the details of which I have been unable to obtain. These, together with numerous other wells, varying from 300 to 400 feet deep, are sunk in what is known as the Paris Basin. The equal temperature of these waters, nearly 80 degrees, would tend to show their common source.

English Bores.

A formation of mesozoic chalk underlies London, forming what is known as the London Basin; and this has been practically speaking, riddled with borings. It may not be generally known, but the sources of the New River, which is one of the feeders of the London Water Supply, derive

their origin from artesian wells at Amwell and Chatfield, yielding some 4,500,000 gallons per diem. The Bank of England, the fountains in Trafalgar Square, and the House of Commons are all supplied by artesian wells, and several of the prisons are supplied from the same source. At Sion House there is a well 650 feet deep, the water rising 4 feet over the curb, sunk in Queen Elizabeth's time. Several breweries and the Kentish Town Waterworks derive their supplies from artesian wells—the latter having a well 900 feet deep. The London Jute Company have a notable well at Ponders End, yielding also a large artesian supply. At many places on the southern and eastern coasts artesian wells exist, extending as far north as Bourne, in Lincolnshire, where a well 95 feet deep yields a supply under sufficient pressure to reach the tallest houses; these are known as "Blow Wells" in the locality. The well at Bourne was bored through Oolitic strata to a depth of 95 feet, with a hole of the diameter of 4 inches. Below the alluvial a limestone formation 32 feet thick was met with, and continued until a stratum of hard rock was met with, 6 feet thick, upon passing through which the tool suddenly dropped 2 feet, and a supply yielding 567,000 gallons per diem rose to a height of 40 feet above the curb. It is a notable fact that the great number of wells in the London Basin have had the effect of reducing the flow to such an extent that wells which were flowing a few years since have now to be pumped.

Algerian Bores.

In Algeria and Sahara boring has been practised from time immemorial, and of late years immense strides have been made by the French engineers, by whom a very large number of wells have been put down, with the effect of rapidly fertilising and populating portions of this arid region. Artesian wells have, as I have said, existed for ages in this

huge ocean of sand, but sunk by the primitive means available to the Arabs and cased with hollowed palm logs, they have not been lasting, and in time have caved in, the flow has ceased, all vegetation has perished from the lack of water, and in some of the cases have disappeared in toto. As far back as 1856, the French engineer, M. Jus, commenced operations in the Oued Rirh, a district of the Sahara, in the province of Constantine, and obtained a well yielding the enormous supply of 1,278,000 gallons daily. This well is called by the Arabs "The Fountain of Peace." The energy of M. Jus and the military authorities have been untiring, and it is reported on 1st October, 1885, that there were in existence 114 artesian wells belonging to the French military authorities and 492 belonging to the Arabs, yielding the enormous aggregate supply of 80,975,000 gallons daily. The oases are again fertile. The wealth of the Oued Rirh has increased five-fold since the first well was drilled, and the production of dates is enormous. In seven years three villages and oases have sprung into existence at Ouriz, in the north of the Oued Rirh, at Sidi Yahia, and Ayata watered by nine flowing wells, yielding a supply of 8,477,000 gallons per diem, and it may be stated that 56 miles of ditches are formed for the utilisation of these supplies. The transformation produced by artesian water upon the sandhills of Algeria is described by the distinguished French engineer, M. Tournel, as amazing. In Austria, Roumania, and Galicia, boring has been carried on to a very large extent, and many of the practical drillers now in the State have gained some of their experience in those countries. The conditions are, I understand widely different, and the boring for the most part undertaken in search of oil.

American Bores.

In America the petroleum industry speedily brought boring to the front, and directed the attention to the vast

supplies of underground waters available; the importance of the results attained have been fully recognised, the information regarding the wells has been carefully collated by the department dealing with it, and a wonderful fund of knowledge has thereby been made available. Artesian wells are reckoned in America by thousands, extending from Montana and North Dakota to the southern portion of Texas. In North and South Dakota, Wyoming, Nebraska, Colorado, Kansas, Idaho, California, Nevada, New Mexico, and Texas, their numbers are incredible. From a recent map I see there are about 3,700 artesian wells alone in the San Luis Valley; in a small area surrounding Denver about 325 are charted; and from the Rio Grande to the Brazos River the country is dotted with them. The number and volume of the artesian wells in America, west of the 97th meridian zone (17,000) enormously exceed what we have in Australia, and the uses they are put to far excels any efforts so far made here. There are many valleys or basins, which, while limited in area, greatly exceed in yield that at present obtained from the whole of the bores in New South Wales. The most noticeable, perhaps, is the San Luis Valley or Park; it embraces portion of the Rio Grande, Saguache, Costilla and Conejos counties; it is hemmed in by the Sangre de Christos Mountains and the main range of the Rockies. It has, roughly, an area of 8,000 square miles; within it are more than 3,700 artesian wells. The Alamosa town well and the Moffat well being the largest. Some 30 miles of irrigating ditches are supplied from the former well.

Other artesian basins, of more or less magnitude, are scattered through the breadth and length of the land, and they enter in no inconsiderable way into its general development. The Denver basin is one that may be mentioned. Artesian water was first exploited there in 1883, and it

occurs in an elongated oval area, some 56 miles long by 32 miles wide. The borings extend over a great portion of it, and embrace Greeley, Colorado Springs, Pueblo, and other places. In Denver City alone, there are some eighty or ninety wells, giving a yield of 2,880,000 gallons per diem. The depths vary to 900 feet. The boring in this basin is remarkably good, many of the wells having been sunk at the rate of from 6 to 7 feet per hour, the cost of drilling being about 8/4 per foot. There has been a certain amount of depletion going on in the basin. Whether owing to the multiplication of wells on the lower lying lands, or to bad work and imperfect casing, has not been definitely ascertained. The latter cause no doubt amply explains the reason in some ascertained cases. An enormous waste is taking place day by day, and if the supply has limitation it may possibly be exhausted in time, simply by waste and extravagance. The water is of great purity, and is used for all domestic purposes. The extent of artesian country reaching from San Antonio to the valley of the Rio Grande and the great Colorado desert is enormous, and much still has to be done there in the direction of boring. In the San Bernardino and Los Angeles districts there are over 1,000 wells. In Utah much has been done; Kansas and Idaho have added their quota of large flowing wells and hold up the enormous yields at Boise city and Moscow as examples. In North and South Dakota a great development—more especially in the use of the flow for irrigation—has taken place, perhaps more than in any other part of America. In Louisiana much has been done, and still more remains to be done. In the Kern valley, from the limited area of 18 × 14 miles, the wells yield some 61,000,000 gallons per diem, most of which is used for lucerne irrigation. It is more in the direction of individual effort, rather than by corporate work, that one finds the artesian water exploited for irrigation, though in the San Bernardino

country the well has entered largely into the works of corporate bodies. No doubt the unrivalled facilities for taking out gravity canals from the numberless streams, and the ease with which appropriations of water from them are acquired in certain favoured localities, has had much to do so far in leaving this development to the individual in less favoured districts. In Honolulu, on the island of Oahu, enormous volumes of water are obtained from artesian wells for irrigation of the sugar plantations, and astounding success and results have been obtained upon the Ewa plantation. Some 275,000,000 gallons per diem, all derived from wells, pumping and flowing, are used for the irrigation of the plantations, the cost including canals etc., being about £13 per acre per annum. The yield, however, is enormous, as much as 11 tons of sugar being obtained from one acre of irrigated cane. Rice cultivation also is largely carried out. The average annual rainfall at Honolulu for the last sixteen years has been 28 inches: maximum 49 inches, minimum 13 inches.

The height to which the water rose originally above the surface in these wells was 42 feet, but, owing to the enormous outflow, this has been reduced to 34 feet, so that depletion is evidently going on, but as the artesian area is limited, this, perhaps is only what might be expected, especially when one remembers that 100 wells on the small area of 50 square miles have an output of 275,000,000 gallons per diem. The duty of water in Honolulu is very high —1 cubic foot per second to 80 acres. The borings are not deep, few exceeding 500 feet, and the waters contain but a small quantity, from 13 to 14 grains per gallon of total solids.

According to Professor Hill's report on the occurrence of artesian water in Texas, there has been no grander development of artesian wells than in the grand and black

prairie regions of Texas. At numerous places through its extent, magnificent flows of water have been secured, and what ten years ago was in many places poorly watered districts now abounds in magnificent artesian wells, which supply water to cities and farms in sufficient quantities to make new industries possible, besides furnishing water to irrigate many thousand of acres. The wells vary in depth from 50 to 2,000 feet; they vary in volume of flow from a gallon per minute to a thousand. The purity of the artesian supply for domestic purposes, and its healthfulness, gave Fort Worth an enviable superiority which her rival cities were not slow to imitate, and as a result of her success every city and village in the prairie region and in fact throughout the State, made artesian experiments. A few of these were put down in unfavourable localities and were failures, but hundreds more were successful, and to day most of the cities of the State, which before this epoch were without good water are now supplied with abundance. The industrial uses to which these waters are put are many. At Waco hundreds of sewing machines in clothing factories, electric motors, wood working machinery and other small industries are run by the pressure of the wells without wasting the water, which is also used for irrigation. When the high cost of fuel in Texas is considered, this use of artesian water becomes an important factor. The greatest use of this water at present is the fact that it brings to hitherto poorly watered farming and grazing lands an abundant supply of water for domestic and stock purposes, making small farms of 100 acres or less possible, where until recently, subdivisions of large areas of land or ranches were impossible. The farmers of the Paluxy Valley under their own crude methods are quadrupling their yield of cotton and grain. There are more than 1,000 flowing wells in Texas west of the 87th meridian of west

longitude. "Their vast capability and adaptability for making secure an agriculture always rendered uncertain under high temperature has become a matter of general understanding." Here, as at other places, much waste is taking place. In the Dakotas, the Texas artesian basin has a rival. I have a tabulated list of some 83 artesian wells, the depths varying from 500 to 1,900 feet, with flows varying from 10,000 gallons per diem to over 4,000,000 gallons per diem, and with pressures up to 177 lbs to the square inch.

The individual records of some of these wells are worth mentioning: The Day-Harrison Well, depth 847 feet, flow 700,000 gallons per diem; 320 acres under irrigation from the well. Richards' Well, depth 917 feet, flow not stated, but 480 acres are irrigated by its flow. Springfield Well, 540 feet, flow 1,184,400 gallons per diem; water used for power to run a flour mill. Beard Well, depth 1,050 feet, flow 1,526,000 gallons used for irrigation. Woonsocket, depth 775 feet, flow used to drive a flour mill.

South Dakota last year took her place at the head of the column of States for the highest general average, taking them together, of crops, including corn, wheat, oats, flax, barley, rye and hay, as a result of the present system of irrigation. From the most reliable information obtainable, the wheat crop in South Dakota this year is estimated at 35,000,000 bushels. The oat crop is the largest and best the State ever produced. Barley is shrunken a little, but is unusually bright and harvested in fine condition. Rye and flax will yield well; the latter is not yet matured, but is doing well and is fast filling. The hay crop is enormous, so great that thousands of acres will not be harvested or otherwise used. The corn, it is believed, will not fall far below 100,000,000 bushels. The reason why South Dakota has not suffered as much from drought as its neighbours is

the fact that there are about 1,000 artesian and flowing wells from the Jim River valley to the Missouri River. The estimated amount of water flowing from each is 100 gallons per minute, or a total of more than 52,000,000,000 gallons per year. Not only do these wells supply water for live stock, but they make thousands of ponds, lakes, and small streams; they fill sloughs, low places, and old lake beds. Many others could be cited, but perhaps sufficient has been said to show to some extent and generally what has been done in boring in America.

New South Wales Bores.

Having shewn generally what has been done in other lands, it may not be out of place to recapitulate briefly the conditions which obtain on our western lands, which have both tried the patience and exhausted the substance of many of our pioneers, and to show at the same time the effect upon these conditions obtained by the means of artesian water, so that those unacquainted with the interior can realise in some degree what its influence means. The arid portion of New South Wales is that embraced by what is generally known as the Western Division of the State, which contains an area of some 79,000,000 acres. This division, made for the purpose of the Crown Lands Act, comprises the whole of the north-western portion of the State, and follows largely in its direction the course of the river Darling. An area of some 26,000,000 acres of this tract of country is defined as "Cretaceous" or artesian water-bearing. Following the course of the Darling and its tributaries, narrow strips of land adjacent to them are rich alluvial flats for the most part of black soil; behind them lie large extents of chocolate and red soils, and æolian deposits in the form of undulating sandhills. The larger area of the country in this division is probably of this latter character. The river flats carry poor distorted specimens of

the Eucalyptus, worthless for the most part for industrial purposes, while upon the chocolate lands and sandhills the only useful timber, and even then confined to certain localities, and sparsely scattered, is the native or colonial pine, and other timbers, the box, gidgea, mulga, and beefwood, stunted at the best, are useful for but little else than fencing purposes. The river flats and plains are generally free from scrubs, and after rains carry a fair growth of the tussocky varieties of indigenous grasses and salsolaceous shrubs, now fast disappearing. The sandhills grow grass and herbs, and at rare intervals stunted shrubs and bushes, many of them edible and fattening for stock. The whole of this division is, with the most insignificant exception, devoted to stock raising; but the intermittent and scanty nature of the rainfall, and the ever and often-recurring periods of drought, together with the other adverse conditions, render the pastoral industry a precarious and far from profitable one.

Only one river worthy of the name—the Darling—a slow sluggish stream, with no great fall in its whole length, navigable in any ordinary season from its junction with the Murray to Walgett, a distance of 1,500 miles, intersects the country. During floods it spreads, and the volume of water flowing to the sea is very great, while during periods of drought the flow ceases, and in parts break into chains of waterholes. The other watercourses or tributaries, of this waterway, are also intermittent in their flow and not navigable, and for the most part consist of miles of dry sandy bottom, with here and there a waterhole of more or less permanency. The frontages of these rivers and watercourses have some value for the pastoral occupancy, and as they can be cheaply improved by the erection of dams, and as they afford an inexpensive though a precarious source of water supply—back from the frontage artificial supplies

are provided by means of excavations and wells—the expensive nature and magnitude of these works necessary to withstand a period of drought render large paddocks indispensable, the object being to make one serve as large an area of country as possible. The disadvantages are at once apparent, when the concentration of large numbers of stock in their daily journey to an from the water, the contingent expense of attendance, the deterioration of the fleece by reason of the dust, the waste and destruction of feed by trampling, and of water by stock swimming, and loss by bogging, are considered.

On the other hand, a well located bore, with channels carrying the flow for miles through paddocks, materially alters the position, and affords a double frontage, as it were, to a running stream, superior in many respects to a river; it admits of smaller paddocks, which will carry far more stock in proportion to a large paddock served with only one watering place. The enormous traffic to and from the water is avoided, and the dust and waste of food is consequently reduced to a minimum. Nor do the stock require the same attention, for the risk of the bogging of weak animals is entirely removed. What the presence of water running through a paddock means to lambing sheep, those following pastoral pursuits can realise without explanation. It is not, I think, an exaggeration to say that a paddock so watered will carry 20% more sheep at less cost than under the first described conditions. The rainfall of the west is but small, and taken all round may be said to average about 12 inches in the year; and even after expensive water improvements are effected, taking season by season, the country will not carry with safety more than a sheep to 8 or 10 acres. To those acquainted with stock raising in more favoured lands, this fact will probably convey an idea of the aridity of the country more than any further

explanation. The general lay of the country is flat, the plains being of enormous extent, and a gradual fall across the State from east to west. This aridity and want of water have been the great drawback to closer settlement in the Western Division, which at the present time supports a scanty and scattered population, for the most part nomadic, consisting of carriers, rouseabouts, and shearers.

Until the discovery of artesian water, the supplies were as I have stated before, derived from wells, for the most part brackish; dams upon the intermittingly flowing creeks, and large prismoidal excavations, in the form of tanks, in the flats and watercourses for impounding the rain-water as it falls. The first essay at artesian boring, as I stated in my first report issued on this subject, was made by Mr. David Brown, of Kallara Station, some twenty years ago, in the neighbourhood of one of the many mound springs which dot this area, which resulted in flowing artesian water, did not then attract the general attention it deserved, and it was not until ten years later that the Government of the State purchased some boring plants, ineffective compared with those of the later type, and with them had some success, obtaining flowing wells also in the neighbourhood of mound springs. It was, however, reserved to an American driller and some spirited capitalists, to really exploit the industry, by introducing the Canadian pole-rig and contract system, which was followed by the Government, after a far seeing Crown tenant, Mr. W. W. Davis, of Kerribree Station, near Bourke, had demonstrated its superiority over the old existing methods. The work, both public and private, has progressed rapidly, and there are still vast areas yet untouched by the drill. How long they will remain so depends upon the energy and forethought of those interested, and upon the wisdom of the Legislature.

SUITABILITY OF ARTESIAN WATER FOR IRRIGATION.

Of the many questions that arise in connection with irrigation, there are none so important as that relating to the suitability of the land and water for the purpose designed. Much has been said on the subject in this State, and the opinions of the pessimist have been frequently expressed adverse to the utilisation of artesian water for irrigation. These have in some instances, been given after a short experience of experiments made without any regard to the conditions under which they have been carried out, and without any effort to ascertain the why and wherefore of the results achieved. The suitability of the water and land considered, so far as the alkaline constituents are concerned, is of the first importance, and has, so far as I am aware, been absolutely neglected in the private enterprise undertaken in this State. No considerable enterprise has been undertaken in America, of late years, without fully establishing a fact, viz. the suitability of the land and water for irrigation purposes, upon which the whole success or otherwise of the undertaking rests, by a reference to the agricultural chemist and analyst. A very great feature of this is made at the University of California, at Berkeley, where the question has been dealt with in an exhaustive and clear manner by Mr. E. W. Hilgard, Professor of Agricultural Chemistry at the University. I visited Berkeley University and had the opportunity of hearing Professors Wilson and Hilgard explain the matter, and was at the same time, furnished with copies of their bulletins dealing with the subject. Professor Hilgard was also kind enough to furnish me with copies of other papers on the subject, prepared by him. One of them, read before the Irrigation Congress, at Lincoln and Sacramento, is so educational and instructive, that any curtailment or précis of it would fail to give us the same grasp of the subject as

the whole paper, it is not very long, so that its inclusion seems justified. Examinations have been made regarding the nature, value, and utilisation of alkali lands, and upon the tolerance of alkali by various cultures, to which I shall refer. The investigations made by the chemists determine first the quantity of alkali in the soil. They are not content in taking the surface soil only, as we have done in cases where analysis of the soil has been made, but they average samples of the soil to a depth of four feet; the soil is further tested to ascertain the natural moisture, or, as it is called, the hygroscopic moisture. This moisture is found in all soils, in accordance with its nature and density. This is taken into consideration with the natural rainfall, and calculation is made as to what amount of water is required respectively by each class of culture proposed. This is of value in obviating waste, and in estimating the quantity of water required to be provided for any proposal. The water is also analysed, and the comparison of the results with that obtained from the soil analyses enables the chemist to advise with no degree of uncertainty. Much could be done here, and no doubt many misapplied efforts and futile expense could have been avoided had such system been generally in vogue.

It should, I think, be laid down as an axiom, that before any irrigation is commenced, an exhaustive chemical examination should be first made of the soil and water. Nearly the whole of our artesian waters have been analysed, and in some instances soils from the surface of the land proposed to be irrigated, the analyses of which have shown that little or no alkali exists in them, while on the other hand, an apparently larger proportion of alkaline carbonates is present in the water than is observed in America. It must, however, be remembered that the basis on which the analyses are made are not the same. The United

States gallon contains 58·328 grains, while that of this country, the Imperial gallon, contains 70·000 grains. Therefore, we cannot accurately compare the two analyses without reducing them to the same base. Now our chemists Messrs. Guthrie and Mingaye, who have carried out our analyses and who have written much upon this subject, have placed the limit of safety upon water which contains from 30 to 60 grains per Imperial gallon of alkaline carbonates, the land containing practically no alkali; while in America the limit runs as high—the land also charged with alkali—as 100 grains per American gallon. The shallowness of soil has been given some prominence for the reason that it has been found to be the cause of failure in many instances.

Professor Hilgard's paper, which I have already referred to, should be read by all interested in artesian well irrigation. It is entitled, "The use of Saline and Alkaline Waters in Irrigation," and was read before the Irrigation Congress at Lincoln and Sacramento in 1897, and is as follows:—

"The vital importance of irrigation in the arid regions, and the consequent high value of irrigation water, offer a great temptation towards the use of waters containing relatively large amounts of saline ingredients, which from the very nature of the case are of very frequent occurrence. The origin of this saline contamination is, of course, the same as that of the alkali lands themselves. Such waters may, in the majority of cases, be considered as the leachings of alkali lands. That the occurrence of the latter is essentially the result of a deficient rainfall, is insufficient in amount to carry the salts naturally formed in the weathering of all soils into the country drainage, as currently happens in the region of summer rains, has been sufficiently explained in former publications of this Station, which have also set forth the means that may be used towards the reclamation of alkali lands for profitable culture.

"It is evident that if alkaline waters are used for irrigating lands already more or less charged with alkali, the amount of the latter may be readily increased to an extent that may render the continuance of profitable culture impossible. As stated elsewhere and is that too well known to many irrigators, this not uncommonly happens even when the purest water is used for irrigation —a very troublesome phenomenon which is popularly known as the rise of the alkali. The causes which lie at the bottom of this process have been fully shown by investigation made at this station. It results from the accumulation, near the surface and therefore within easy reach of the roots and root-crown of culture plants, of the alkali salts which for long periods have been accumulating in the depths of the subsoil, near the level to which the annual rainfall reaches, the amount of irrigation water used, being usually no more than is necessary to wet the land to a depth absolutely required for the welfare of the crop, but not sufficient to carry the alkali salts into the country drainage. The accumulated salts are dissolved and subsequently by surface evaporation of the water, are themselves carried near or to the surface, until the entire mass formerly distributed between 3 or 4 feet of soil and subsoil, is accumulated within a few inches of the surface, where they will do the most harm to vegetation. The injury to the latter being in the majority of cases due to a corrosion of the root-crown by the strong saline solution.

"If, as is well known, this happens even when the purest water is used for irrigation, the evil must be aggravated in proportion to the additional amounts of salts carried into the land by the saline irrigation waters. In the case of some waters used for irrigation within the last few years, the alkali content has been so great that soils heretofore wholly free from alkali contamination have been converted into genuine alkali lands, incapable of being used for ordinary cultures but only for such as are tolerant of such salts. In several instances, this has been done, despite the warning given by this Station as to the inevitable results of the use of such waters under any ordinary conditions or modes operating,

and among the reasons assigned for so doing has sometimes been the unquestioned fact that luxuriant vegetation is found growing along the shores or margin of lakes and streams to which the warning applied. It therefore, seems necessary to explain why this is so, and that it is perfectly consistent with the correctness of the objections made to the use of the water.

"As a matter of fact, but few waters naturally occurring—such as the ocean, Great Salt Lake, Mono Lake, and others—are sufficiently strong to prevent or destroy vegetation of which they bathe the roots, so long as their saline strength is not increased and concentrated by evaporation. According to the investigations made in Europe early in the century, it takes over 1,000 grains of common salt per gallon to prevent the growing of most culture plants in water; a few will tolerate as much as 1,300. According to our own experience, plants will tolerate more than twice as much of glauber salt (sulphate of soda) as they will of common salt, but carbonate of soda is nearly three times more injurious than common salt to the growth of plants. As these three salts—sulphate, carbonate, and chloride of sodium—constitute in varying proportions the bulk of what is known as "black" and "white" akali, it will be readily understood that, according to the nature of these salts, and of others occasionally accompanying them, the tolerance of plants for them may vary greatly for the same total amounts of soluble salts contained in the water. For this reason alone, then, it is not easy to give figures or percentages stating exactly how much alkali, in soil or water, a plant will tolerate. A series of elaborate culture tests on alkali that have been made during the last five or six years have shewn approximately the tolerance of some of the more important culture plants for alkali salts. Some of these figures have been given in former reports, while others are given for the first time in the present one, and these experiments and investigations are being continued under the numerous varying conditions that may determine tolerance or intolerance.

"Among these varying conditions apart from the composition of the alkali salts above referred to, the most important appears

to be the nature of the soil in regard to 'perviousness' and 'lightness' on the one hand, and 'closeness' and heaviness' on the other. For light soils hold a smaller amount of water in their pores than heavy ones, and permit more readily of 'leaching' through, by which the soil may be freed of its alkali salts. Clay soils, on the contrary, hold a large amount of water more tenaciously, and it is difficult, sometimes impossible to effect 'leaching out' of alkali salts unless by the aid of the underdrains.

" These preliminaries being understood, it is not difficult to see why and how alkaline irrigation water may be used with impunity on some lands while promptly fatal to the producing powers of others: one and the same amount of irrigation water may in sandy land readily penetrate to the natural subdrainage, thus preventing the accumulation of alkali in the soil by surface evaporation; while used on an "Adobe" it will not only penetrate to the subdrainage, but, remaining within a few feet of the surface, will in a short time evaporate there, carrying upward with it the entire mass of alkali salts in the soil undiminished. In such lands, it is only by long soakage that the alkali salts can be sensibly diminished; it is utterly idle to attempt to wash them off the surface by a rush of water, for at the very first touch the very strong solution first formed is absorbed into the dry soil and thereafter penetrates downwards instead of upwards. It is thus obvious that when we can apply to a fairly pervious soil an amount of saline irrigation water large enough to wash out into the subdrainage any former accumulation, and when this operation is repeated at intervals not too long, or surface evaporation allowed to progress to too great an extent, relatively strong saline waters may be used for ordinary culture plants with impunity, they being there substantially under the same conditions as the luxuriant vegetation commonly found on the margin of alkali lakes. But it is quite otherwise when the same water is used according to the ordinary practice of irrigation, viz., only to the extent required to wet the root system, repeating this wetting at such intervals as may be required for the welfare of the crop, but never to such an extent

as to wash accumulated salts out of the land. The total amount of salts contained in the successive masses of irrigation water are thus accumulated and retained in the soil, and this accumulation soon becomes formidable if the water is at all strongly charged or if the soil should contain an amount of alkali closely approaching the limits of tolerance.

"When the amount and kinds of salts in the water have been determined by a chemist it is a simple question of arithmetic to estimate how much alkali is added to the soil each year, and accordingly to calculate the number of years within which the soil will become incapable of bearing ordinary crops. To illustrate this by example :—Suppose a water used for irrigation to contain 100 grains of alkali salts per gallon, as in the case of Lakes Elsinore and Tulare, in California, and that irrigation is used to the extent of supplying an annual deficiency of 15 inches of rainfall (or 15 acre inches), to wit, 408,375 gallons, this amount of water would contain something over 5·300 lbs. of salt, and were these fully retained in the land, this addition would be made annually. Comparing this with some of the actual amounts found in land approaching the limits of tolerance, we find that in the experimental plot at the Southern California substation, which contains within the first three feet from 7,000 to 12,000 lbs. of comparatively mild alkali (chiefly glauber salts) most of the commonly cultivated grasses clover and vegetation refuse to grow or fail to produce satisfactory crops, while, nevertheless, excellent high-grade sugar beets are grown upon the same ground. At the Tulare substation it was found that sugar beets failed to produce satisfactorily when 18,000 to 20,000 lbs. were contained in the land. Nearly the same limit of toleration applies there to wheat, while barley will under favourable conditions, resist as much as 32,000 lbs. to the acre in 3 feet depth, which may be considered as its extreme limit of tolerance. But, on the same land, ordinary fruit trees already planted either die or maintain but a feeble existence. Citrus trees of a considerable age have died out under these conditions, so soon as the soil in which they grew was by

irrigation raised to 15,000 lbs. per acre, or even less, of saline contents. While the above figures are mere approximations, obtained under special conditions and varying for different soils to a greater or less extent, they are quite sufficient to show that the annual addition of, say 5,000 lbs. of alkali salts to any soil cannot be long continued with impunity, always supposing that the whole of the alkali contained in the irrigating water remains upon the land. In many cases, especially where water is scarce, this is strictly true, and three years of irrigation has sufficed to render land formerly capable of producing all kinds of crops, unfit for any save those which, like the beet, the sunflower and others, are specially tolerant of alkali salts. It would take but few years of such regime to kill out any citrus orchard, and deciduous orchards would follow in short order.

"The subject is really simple enough to be understood by any-one capable of doing a sum in arithmetic, and of judging to what extent, if any, his customary method of irrigation relieves the land of alkali salts that may have been introduced by irrigation water. The principal of the whole matter may be summed up as follows: When water containing any considerable amount of alkali salts is used for irrigation it should be used very abundantly, at least once a year, so as to wash the alkali through into the subdrainage if possible. On light soils this can be readily done; on heavy soils it is extremely difficult to do it without the aid of under-drains, and such lands in their natural conditions are, therefore, most readily injured by the use of alkaline irrigation water. The question is frequently asked, how much alkali in water will render it objectionable for irrigation use? From what has been already said, it will be easily understood that the question does not admit of a definite answer, since both the quality of the saline contents and the nature of the soil, together with the possibility of liberal and judicious use of the water require to be considered.

"Broadly speaking, any water unfit for domestic use on account of its saline contents should be used for irrigation only after an

examination of the nature and amount of the latter. The limit usually given for drinking waters is 40 grains per gallon.

"Suppose that all, or nearly all of such matter were gypsum, however, the water would be still good for irrigation, and in fact, be preferable to purer water in most cases. In some good irrigation water in Texas and New Mexico, flowing from gypsum beds, as much as 160 grains per gallon are found; but these waters are wholly unfit for drinking purposes. On the other hand, were a water proposed to be used for irrigation found to contain that amount of common or glauber salts, it would be difficult to use it without injury, save on the very highest land and for very tolerant crops. But even 40 grains per gallon of carbonate of soda would be at least equally dangerous, unless in conjunction with gypsum to transform the black into the white alkali. Even water containing 20 grains of the former, has, in some instances, caused serious trouble in three or four years. Each case must, therefore be considered upon its merits, with due regad to all the surrounding circumstances."

GENERALLY.

What I have written regarding this subject must, I fear, convey but an inadequate idea of what has been done in America. I have given simply isolated instances of the results from individual enterprises. These could be multiplied one hundred fold and then no adequate idea would be conveyed of the magnitude of what is being done, and the general effort that is being made to supplement by irrigation the production under natural conditions. It will, of course, be gathered that the conditions obtaining in America are more favourable for irrigation than in this State. We have none of the snow-clad mountains and the extensive valleys and running streams that exists there, nor have we the teeming population and enormous market, nor their rail facilities. We can devise but few of the large gravitation schemes which are having such an enormous influence

upon the arid lands. Neither have we to such an extent the economic advantages afforded by the extensive and shallow artesian supplies obtainable in some of the States, and which have been factors in more than one large scheme of development. We have however, on the other hand, millions of acres of fertile land, only requiring the help of irrigation, within the area of an artesian basin, which perhaps, has no equal in the world in extent and volume of supply. In our own State the basin embraces an area of some 62,000 square miles, in which we have so far—to use an expression which seems to me to convey the smallness of what we have done in comparison with the area on which we have done it—put some 200 pin pricks, in the shape of borings.

The absence of the facilities afforded by numerous stream and snow clad ranges to feed them in this State should be no cause for discouragement and apathy while we have the artesian system to fall back upon. Nothing can be achieved or gained by sitting down and allowing the land and our underground supplies to lie idle while our stock are dying in millions, because the people say "it wont pay to irrigate for stock feeding," "the supply wont last," etc. The hardy pioneers of American irrigation thirty years ago, under infinitely greater disabilities than we labour under, crowded out from the centres of population in their struggle for existence, did not sit down, but worked and risked their labour and their all in an undertaking which in those days was viewed in a carping spirit much the same way as it is here. Necessity compelled them. Although America has at present greater advantages in market and population than we have, that is no reason why we should not attempt some development of those facilities that are afforded us. We can start under auspices as good as existed there, even in some respects better. We have but little or nothing to

fear regarding the suitability of the great majority of the waters from our bores for irrigation, provided the conditions laid down by Professor Hilgard are observed.

The evidence that is afforded by the reports and by ocular demonstration is so strongly corroborative of this expression of opinion that we take it for granted that the suitability of the waters may generally be conceded, subject of course, to such limitations as may be imposed by the revelations of their analyses and those of the soils. Thus we shall find that the majority of the bore waters may be used. That being so, it is discouraging to find so little has been attempted, a position no doubt due to a want of knowledge and an appreciation of the subject, and perhaps to the generally accepted idea that it will not pay. It therefore seemed to me that there was distinctly room for some explanation of the subject such as I have endeavoured to give in the preceding pages. Enough has, I think, been said to make a good case for the use of artesian water for irrigation, from the point of view as to the suitability of the water.

The number of Government Bores that have been completed to date is as follows:—Flowing bores 74, the depth is 132,577 feet, and the total flow received from the bores is 54,239,393 gallons per diem. There are 23 pumping bores and 13 have proved failures, The number of private flowing bores is 109, the depth 195,040 feet, and the flow reaches 84,995,000 gallons per diem. There are 20 pumping bores and 16 have proved failures.

THE MEASUREMENT OF THE FLOW OF STREAMS AND ARTESIAN BORES, AS CARRIED OUT BY THE PUBLIC WORKS DEPARTMENT OF NEW SOUTH WALES.

By H. S. I. SMAIL, B.E., Assistant Engineer.

[*Read before the Engineering Section of the Royal Society of N. S. Wales, July 20, 1903.*]

IN determining the flow of any stream two factors are necessary, viz.:—the area of the cross section, and the mean velocity of the stream at that section, then $Q = Av$. There is no great difficulty in measuring the first factor A except in streams of enormous volume, like the Mississippi, but to determine v is quite another matter, chiefly for the reason that the velocity of any point in the cross section is constantly changing, even when Q and A remain constant and consequently the mean velocity. Many observers have noticed the phenomenon of "pulsation of moving water."[1]

D. F. Henry, says[2] "All water in motion has an intermittent velocity increasing and decreasing according to some unknown law." He further states, "The lesser fluctuations have a duration of 30 to 60 seconds, and the larger ones from 5 to 10 minutes. They do not seem to be synchronous with the surface fluctuations and are smaller at the surface than at the bottom."

But the motion of water in an open channel is not simply a succession of impulses, on the contrary it is very complex,

[1] Vide J. B. Francis, Trans. Am. Soc. C.E., Vol. VII., p. 111; Capt. Cunningham, Proc. Inst. C.E., Vol. LXXI., p. 7; Prof. Unwin, Proc. Inst. C.E., Vol. LXXI., p. 348, and many others.

[2] Journ. Franklin Inst., Vol. LXII., p. 323.

even in such a channel as the Sydney Water Supply Upper Canal with constant cross section, regular grade, and cement lined, the author has observed the water boiling and swirling, some particles moving up, others down, but all having a general motion down stream. This is even more noticeable in a natural channel or river with ever varying cross section and constantly altering grade.

Any engineer engaged in observing the flow of rivers must have a knowledge of the above phenomena, as, if only a few observations of velocity are made, these may be nearly all at a time of maximum impulse and thus the measured mean velocity be too large or *vice versa*, and if the true mean be obtained it will only be by accident.

Methods of Measuring Velocity.

Only two methods of measuring the velocity of streams will be considered at any length, viz :—rod floats and current meters; as in a large stream, they are the only methods that have any pretentions to accuracy. Weirs are impossible except for small streams owing to expense; these will be dealt with later on under artesian bores. Surface floats have been used in a few instances, but they are very unreliable, from the fact that the surface velocity of a vertical does not bear a constant ratio to the mean velocity at that vertical, sometimes it is greater than the mean, sometimes equal to it and sometimes less. Even if it did bear a constant ratio, any wind blowing would vitiate the results.

Double floats have also been used, but in the author's opinion the results are not reliable, in fact he considers that the double float is even worse than the surface float. Cunningham and others speak highly of this form of float, but other skilled observers including D. F. Henry, U. S. Assistant Engineer, who had charge of the field work of the gauging of the outlets of the Great Lakes, and who

has used this and other methods for deep rivers, says[1] "All the objections to the surface float apply with greater force to the double float, and additional ones peculiar to itself." Prof. E. C. Murphy of Cornell University, says, "It is impossible to determine the exact position or depth of the lower float,"[2] and this is the great difficulty that the author has found with this method. Again the upper float may drag the lower one or *vice versa.*

Slope formula.—The mean velocity may be computed from the slope of the water surface, the dimensions of the cross section and a knowledge of the roughness of the sides and bottom. The one most largely used is Kutter's—

$$v = \frac{41{\cdot}6 + \dfrac{1{\cdot}811}{n} + \dfrac{{\cdot}00281}{s}}{1 + \left(41{\cdot}6 + \dfrac{{\cdot}00281}{s}\right)\dfrac{n}{\sqrt{Rs}}}\sqrt{Rs}$$

Where v = mean velocity in feet per second.
s = surface slope.
R = hydraulic radius.
n = a ratio varying from ·009 for well planed wooden channel to ·035 for rivers in bad order, overgrown with weeds or covered with stones.

It is claimed that this formula applies to streams of all sizes, from small sewers to large rivers, its constants being determined from gaugings by Bazin, Humphreys and Abbot, Cunningham and many others.

There is no doubt as to its accuracy where applied to artificial channels with constant cross section, but it is absolutely valueless for a natural stream of any size, and this same remark applies to all general formulas, from the great difficulty in measuring the slope. The author has endeavoured to measure the slope at different gauging sites,

[1] Journal Franklin Inst., Vol. LXII., p. 167.
[2] Water Supply and Irrigation Papers, United States, No. 64, p. 15.

but has found that the slope measured over 2,000 feet differed from that over 1,000 feet, and that the slope at one side differed from that at the other side.

In practice the slope must be measured over one or two thousand feet, with a level and staff, and it is evident that the slope thus found is not the 's' in the formula, so it must be assumed that this is equal to the local slope or bears some definite relationship to it, which is not correct except by accident.

Starling says,[1] "Even the local slope is not constant, but varies greatly from bank to bank." T. G. Ellis found that by measuring the slope carefully over 100 and 400 feet lengths, and using the best modern formulæ, the discharge so found differed by 50 to 250 per cent. from that found by actual gauging. He thinks the slope is so uncertain an element that slope formulæ are of little value.[2] Cunningham came to the same conclusion in experiments on the Ganges Canal.[3] Hamilton Smith Jnr., says,[4] "All determinations of the flow in large streams depending on the factors s, R, and v are necessarily very unreliable."

Rod Floats.—This is the best of all float determinations of velocity, and was practically the only method used by the department till the beginning of 1902. The first authentic gaugings in New South Wales were made by Mr. H. G. McKinney, M. Inst. C.E., in 1886, who adopted the rod floats in preference to the current meter, for the reason that the only meter at his disposal was one of the Rèvy pattern, and he states "In my time current meters were so unreliable that I did not care to go on using them; I came to the conclusion that the method I used (rod floats) was the better one. I tried a Rèvy meter in still water,

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[1] Trans. Am. Soc. C.E., Vol. xxxiv., No. 5, p. 393.
[2] Trans. Am. Soc. C.E., Vol. xi., p. 23.
[3] Proc. Inst. C.E., Vol. lxxi., p. 11. [4] Hydraulics, p. 191.

and found that it recorded so unsatisfactorily, that I decided that there was more objection to it than to the rods."[1] Cunningham seemed to have a similar opinion about rod floats and current meters of the above type.

In the author's opinion the rod floats are better even in rivers with irregular beds, than meters of the Rèvy pattern with recording dials under the water; this will be referred to later on under current meters. The method of procedure in gauging a river with rod floats is as follows: First of all the gauging site has to be selected; and the following applies to both rod floats and current meters. The ideal site is on a straight reach, far enough from a bend to be out of its influence; the bed should be permanent and not stony. The banks should be sufficiently high to contain all the water at the highest stages. The section should be free from all disturbing influences, such as bridge piers, etc. It should be such a place that the velocity is measurable even in the lowest stages, that is it should not be in a pool. As most of our gauges are bolted to bridge piers, gaugings cannot be taken at this section, so the site should be as near the gauge as possible. Seldom are all these advantages to be found at the one site, scour of bed or silting give trouble, at high stages the velocities are too great and at low stages too small to measure accurately, so that the engineer must make the most of the best site he can find, always having in mind the desirable and undesirable qualities.

When rod floats are being used, a search for a length of river with even cross section should be made, as a rule this will not be found, but often a place can be found in which a middle cross section is a mean between an upper and a lower one. Thus at Cowra at the gauging site for rod floats

[1] Minutes of Evidence Interstate Royal Commission on River Murray, p. 276.

selected by the author, the area of the middle cross section on Aug. 29th, 1901 was 2,328 sq. ft. and the mean of the cross sections was 2,320 sq. ft. Again on Aug. 26th 1901, area of middle cross section 1,086 sq. ft., mean of the three cross sectional areas 1,100 sq. ft. When the site has been fixed upon, a base line is laid down on the left bank from 50 to 200 feet long, according to circumstances and parallel to the flow, a peg is driven in at each end of this base line and one in the centre. Cross sections of the river perpendicular to this base are taken from each peg, supposing of course that a site has been selected as mentioned above at Cowra, if not more cross sections should be taken and the mean taken. The cross sections are taken with level and staff from peg to water's edge, thence by sounding to water's edge on right bank, then again by level and staff to the top of the right bank.

A bench mark is established at the gauging site connected by levels to the gauge and to a Water Conservation bench mark, so that the RL of the water surface can be taken at each observation. Wires tagged at each ten feet are then stretched across the river at each cross section. These wires should be as near the water surface as is convenient; as a rule the author places them about 3 feet above to allow a boat to pass beneath, so that the floats may be followed and picked up after travelling the required distance.

The rods used by the author consist of 1 inch pine rods, with sheet lead wrapped round them to sink them to the required depth, and a stock of various lengths is kept in the boat. The rods are sunk so that only about ½ inch projects above the water surface, to minimise the effect of any wind that may be blowing. The tops of the rods are painted a bright red, so that they can easily be distinguished from the bank. A rod of the required length is let go from

the boat about 30 or 40 feet above the upper section, so that it may acquire the full velocity before crossing the section. The exact time of the day when each rod passes beneath each wire is noted from the bank, and the distance on the wire noted from the boat. The author has found that an ordinary watch with seconds hand gives the best results, it can easily be read to half seconds. Then the time taken by the float to pass from the upper wire to the lower wire, into the distance between these wires, gives the mean velocity of the vertical, where the float cuts the middle wire, if the site has been judiciously chosen.

When a river is rising or falling rapidly, it is impossible to measure three or more sections at each gauging, in the time at one's disposal, although one can be easily be done, and if the middle cross section is practically the mean of all the cross sections, it may be taken as the cross section over which the discharge is measured. If a float strikes any obstacle on its run, such as a snag, etc., it is discarded, also if it takes a diagonal course through meeting eddies, not an uncommon occurrence even in straight reaches in made channels.

The middle cross section is then divided up into several partial areas. Let the width of each partial area be b feet. Then total discharge $Q = b\,(v_1 d_1 + v_2 d_2 + \ldots\ldots)$ Where d_1, d_2, d_3, etc., are the mean depths of each partial area, and v_1, v_2, v_3, etc, the measured mean velocity in each of these partial areas. The mean velocity of the whole section is then computed by dividing the total discharge by the total area.

Advantages and disadvantages of this method.

Advantages.—It is probably the very best method to use in an artificial channel of constant cross section, with floating grass and weeds, where a current meter would not be

reliable. Captain Cunningham gives the following advantages:—[1]

(1) They interfere less with the natural flow of the water.
(2) They measure velocity direct.
(3) They can be used in a stream of any size.
(4) They are not affected by silt and weeds.
(5) They measure forward velocity.
(6) They can be made by common workmen.
(7) They are cheap.

It is quite true that the floats interfere very little with the flow, but this is also true of a well designed current meter with a screw fan. They do not measure mean velocity direct, but each rod only measures the velocity of a particular impulse. Cunningham himself admits that about 50 rods must pass one vertical to obtain the mean velocity of that vertical. It is a common practice to send a few floats past each vertical, and only make use of those that agree together and cast out those that disagree. This is totally wrong; they should all be made use of and the mean taken. They certainly cannot in the author's opinion be used with any degree of accuracy when the depth is greater than 20 feet. They are not affected by silt and weeds, they do measure forward velocity and they can be made by common workmen, but when many gaugings have to be taken they most certainly are not cheap, when it is considered that it takes twice as long to make a gauging with the rods as with the current meter, even when only two or three floats are sent past each vertical, and therefore we only get the mean velocity of two or three impulses, and again on the New South Wales rivers, when high, the water level fluctuates so rapidly that there is only time to send one rod past each vertical, and therefore, as stated in the beginning of this paper the computed discharge may be too high or too low.

[1] Proc. Inst. C. E., Vol. LXXI.

It is partly to this fact, in the author's opinion, that the individual gaugings in most cases lie so irregularly about the mean rating curve for each gauge, as the individual current meter gaugings are much more regular. It is impossible to entirely get rid of the action of the wind. On irregular beds such as most natural streams have, the rod must be short enough to pass over the shallowest part of its run, and may therefore and indeed in the majority of cases is too short for the greater part of the run, therefore the velocity as given by the rods is too great. From a comparison with current meter gaugings the author has come to the conclusion that the gaugings taken on the New South Wales rivers with rod floats are about ten per cent. too high.

Current Meters.—By far the most accurate and speedy method of gauging a natural or artificial stream is by means of the current meter, provided the meter is of good pattern and has an electrical connection registering the number of revolutions above the water surface. Murphy says,[1] "The meter without some electrical device for indicating to the observer the revolutions in a given time, and which must be lifted out of the water to read the revolutions, is a thing of the past. Too much time is lost in making the readings. The acoustic meter is not a success, the clicks are not sufficiently loud to be heard where the water is deep and noisy."

The meter adopted by the Public Works Department is one made by Amsler-Laffon registering each fifty revolutions by ringing an electric bell. The author has had one of these meters in use for about 18 months, and although used in very dirty and muddy water for the most part, it has altered very little in rating since it was first rated. The

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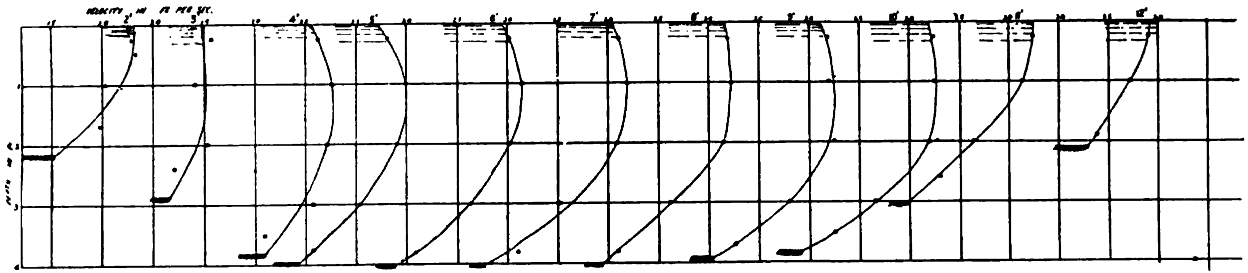
[1] Water Supply and Irrigation Papers of the U.S. Geological Survey, No. 64, p. 22.

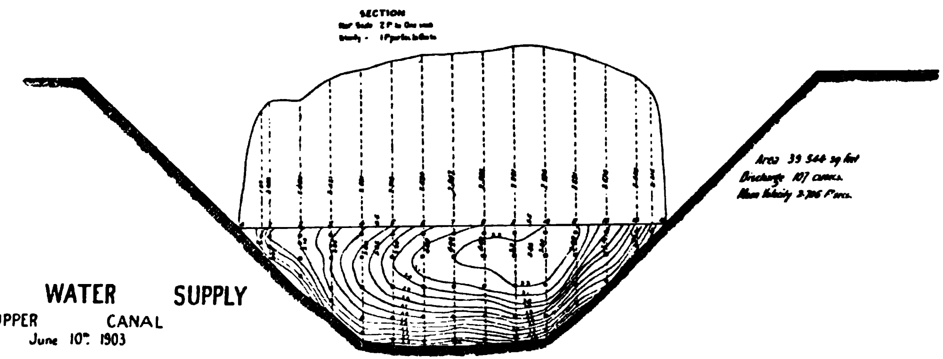
disadvantages of the current meter are few. It cannot be used where there is much floating weeds or grass. It requires rating before use and frequently afterwards. It must be used with care. But it gives integrated or mean velocity. It can be used on streams of all sizes. Gaugings can be taken with more rapidity and accuracy than with rods, and they are cheaper in the end, as fewer men are necessary. The meter adopted by the department was originally intended to be fixed on a metal rod so that it could be held rigidly, but the author has had a few alterations made so that it can be suspended by the insulated copper wires. The meter is entirely free to turn in any direction, the screw being kept facing upstream by a four blade tail. The meter is kept from being swept down stream by leaden weights, which vary according to the velocity. This is a very convenient arrangement, as the meter can be raised or lowered very quickly to any desired position on the vertical.

It is open to only one objection, and that is, it is uncertain whether it is exactly normal to the plane of the section, but the meter always has a slight sway backwards and forwards through a small angle, and according to Professor Unwin[1]—"Supposing it to sway backwards and forwards through an angle of 40° the error of observation due to its position would not exceed 3 per cent." From observations by the author when possible, the angle of sway was more likely from 5° to 10°. At a recent test of two new meters on the Sydney Water Supply Upper Canal, the author used a suspended meter without any loading weights, so that the meter was swept back a little by the current, yet the discharge computed from his observations only differed from one by Mr. Surveyor Shute, taken with meter held rigidly at the same time by 1·7%, and from one by Mr. Surveyor White by 1·1%, also with meter held rigidly.

[1] Proc. Inst. C.E., Vol. LXXI., p. 41.



Vertical Velocity Curves



SYDNEY WATER SUPPLY

UPPER CANAL

June 10th 1903

In a large river it is impossible with the boats at one's disposal to hold the meter rigidly. As before described, (see rod floats), the site is selected but only one section is to be measured, and as before a tagged wire is stretched across, two others are also stretched for holding the boat in any required position; the insulated wires with the meter and weights suspended pass over a sheave at the end of a pole projecting from the boat, so that the meter is well clear of the boat.

Two methods may be used with such a current meter as is adopted by the department, (*a*) multiple measurements (*b*) unit measurements. Method (*a*) is the more exact and when the water surface does not fluctuate is the method always adopted by the author. In this method the velocity at several points in each vertical is measured, at the surface and each one or two feet down to within ·4 feet of the bottom; from these a vertical velocity curve is drawn and the area of this divided by the depth gives the mean velocity of the vertical, as a rule the author gives a run of 100 or 150 revolutions at each point. The verticals are 10 or 20 feet apart across the cross section, depending upon the observer's knowledge of the gauging site; they are closer together as a rule near the banks. When the mean vertical velocities have been computed, the discharge is obtained as in the case of rod floats, being the sum of each partial area into its mean velocity. By this means it takes the author about two hours to gauge a stream like the Murray or Murrumbidgee; of course if a meter of the Rèvy type were used which has to be taken out of the water after each setting to read the dial, it would take much longer, in fact not nearly the same number of points could be observed, and again it has to be assumed that the meter takes up the velocity the moment it is released by the wire attached to the brake, and again that there is no slip of the

dials when the brake is again put on, neither of which assumptions is true.

GAUGING MURRUMBIDGEE RIVER.

Method (*b*) is the most exact method when the water level is fluctuating rapidly, and is being made use of at the present time by the author at Gundagai, where the Murumbidgee is rising at the rate of 8 or 9 feet per day. This consists of giving the meter a run of 500 revolutions at one point on each vertical, as no matter whether the surface velocity be the greatest or whether the maximum velocity be below the surface, a point at which the velocity is equal to the mean remains remarkably constant at a certain point below the surface at each vertical. Humphreys and Abbot give this point as ·63 depth at each vertical. T. G. Ellis gives ·64 depth, and Wheeler and Lynch give ·67 depth. The Cornell experiments by E. C. Murphy agree with the latter, but they as well as those by Wheeler and Lynch were made in flumes or channels having a greater ratio of depth to width than on most rivers.

From a consideration of some 60 vertical velocity curves on the Sydney Water Supply Canals (upper and lower),

Lachlan river at Cowra, Murrumbidgee river at Hay and Gundagai, Murray river at Albury and Tocumwal, the author is of opinion that a single observation at ·64 depth at each vertical gives a very close approximation to the mean velocity of that vertical; this agrees with the result obtained by T. G. Ellis.

In order to obtain accurate results the meter is rated frequently, at least once a month and sometimes oftener, but by exercising great care in cleaning and oiling there is very little difference between the first rating and the last one made, after 18 months use in very muddy water, except at very low velocities.

Gaugings are taken at various stages of the river and a mean curve drawn through the points plotted from individual gaugings, and from these the discharge at any height of the river is read off. If closely looked into it will be found that three curves can be drawn one for rising river, one for falling river, and one for stationary rivers, but for ordinary purposes this is an unnecessary refinement, and a curve is simply drawn through all points disregarding the state of the river. From these curves rating tables for each gauge can be tabulated which shew the discharge for a given gauge reading, of course these will alter as the river bed alters so that discharge observations should be made frequently and the tables corrected.

Artesian Bores.

Acting upon instructions from the Principal Engineer, Mr. L. A. B. Wade, A.M.I.C.E., the author some time ago started to make a detailed examination of the flows and pressures of the artesian wells of this State. Up to the present only the bores of the Moree district have been so done. According to the instructions each bore had to be freely flowing for 48 hours before the normal flow was measured.

The author had a portable notch board made with crest 2 feet long. The crest and sides of the notch were of wrought iron bevelled on the down stream side. The head of water passing over the notch was measured by a hook gauge reading to ·01 inch and approximating to ·005 inch; this he had made in Sydney.

The normal flow was first measured at intervals for 24 hours, to see if any variation took place in the flow. In the flows already measured no such variation was observed. The bore was next shut down by the valve till the pressure gauge read 25 lbs per sq. in., and the flow again measured. It was then shut down till the gauge read 50 lbs per sq. in., and the flow again measured, and so on till the bore was entirely shut down when the pressure was again read. The bore was kept shut down till the pressure reached its maximum, which took some time, a different period for each bore. This last pressure is the hydrostatic pressure. After the pressure reached its maximum the bore was opened full again, and the flow again measured to see whether there was any increase, but only in one case was an increase observed, viz., at the Wollabra bore, one with a very low hydrostatic pressure.

Tests were also made at the Caryunga and Dolgelly bores, only 7 miles apart, to see whether closing down one of them had any effect on the flow of the other, but none was observed. The temperature of the water of each bore was taken. The greatest difficulty in measuring the flow was found in fixing the hook of the gauge to the same level as the crest of the notch. This was done by means of a 14 inch dumpy level and a light staff with a target, this was checked and rechecked about 10 or 12 times at each bore, and the reading on the gauge taken. The author did not fix the zero of the gauge to the level of the crest, but had the zero somewhat below, and the difference between the read-

ing of the water level and the reading when fixed at crest level, gave the head.

A section of the channel was taken at the hook gauge, and the discharge as computed from the observed head applied to it, to see whether there was any appreciable velocity of approach, if there was, which happens very rarely, the equivalent head was computed and inserted in the formula used given below, but as a rule this equivalent head was vastly less than could be measured with the hook gauge, so was neglected.

The author considered that the formula given by Hamilton Smith, Jnr., was much more suitable for the small notch that he was using than Francis' formula, as the notch was only two feet long and heads only about 5 inches at most.

The formula used is

$$Q = c\,\tfrac{2}{3}\,\sqrt{2g}\;b\,(H + \tfrac{4}{3}\,h)^{\frac{3}{2}}$$

Where Q = Cusecs.
g = acceleration due to gravity.
b = length of crest.
H = head as measured by the hook gauge.
h = head due to velocity of approach.

A curve was drawn by plotting the following value of c and corresponding effective heads:

Effective head in feet.	Coefficient c.
·1	·646
·15	·634
·2	·626
·25	·621
·3	·616
·4	·609
·5	·605
·6	·601
·7	·598
·8	·595
·9	·592
1·0	·590

From this curve the coefficient for any head between ·1 ft. and 1·0 ft. is easily read off.

The whole work of river and artesian bore gauging is done under Mr. L. A. B. Wade, A.M.I.C.E., Principal Engineer for Water Supply and Sewerage, Public Works Department. The author has carried out the field work for the past three years, and up to the present has done all gaugings made with the current meter. The author has made free use of the Water Supply and Irrigation papers of the United States Geological Survey in the first part of the paper dealing with the pulsations of flowing water.

THE MURRAY WATERS.

By R. T. McKay, C.E.

Abstract of Lantern Lecture.

[*Delivered to the Engineering Section of the Royal Society of N. S. Wales, July 24, 1903.*]

THE introductory portion dealt with the difficulties experienced by the Federal Convention in arriving at a satisfactory solution of the rivers question. It was eventually agreed by the Convention that trade and commerce, which embraces the navigation of the rivers, should be left to Federal control, while the States should be allowed a *reasonable* use of the waters of the rivers for water conservation and irrigation. The Murray Basin covers the immense area of 414,253 square miles, or 265,121,920 acres, being about one-seventh of the area of the Australian Continent. A great and disappointing disproportion exists between the volume of water which reaches the Murray

River and the immense territory drained; only 158,499 square miles make any effective contribution to the flow, whereas 255,754 square miles are set down as non-contributing. The two great reasons for disparity between the area of the catchment and volume of flow are:—(1) the almost level character of the catchment, and (2) the rainfall over the deltaic area is distributed through so many days of the year that it is quickly absorbed, and very little water flows off. As an instance, the records of the Booligal district, extending over a number of years, show the average annual rainfall to be 12·24 inches, with an average of forty-four rainy days per annum. The following table shows the contributing and non-contributing areas of the four States in square miles:—

State.	Contributing area.	Non-contributing area.
Queensland	67,690	36,835
New South Wales	75,499	158,863
Victoria	15,310	35,669
South Australia	nil	24,387
	158,499	255,754

If rainfall to the extent of only five inches per annum over the immense catchment area of the Murray Basin actually reached the river, after making a liberal allowance for evaporation and percolation, the annual discharge in the South Australian portion of the river would exceed 3,000,000,000,000 cubic feet of water. This would at once settle the question of navigability, and allay the fears of the South Australians respecting diversions by the upper riparian States for the purposes of irrigation and water conservation.

Lakes Alexandrina and Albert and the channels at the Murray mouth cover 300 square miles, and a large quantity of water, estimated at about 42,000,000,000 cubic feet per annum is lost by evaporation. South Australia contends

that not only the volume lost by evaporation should be made good, but also a sufficient volume should be sent down the river channel to maintain a navigable depth, and keep the lakes in a state of freshness.

The proposals made to provide a navigable entrance at the Murray mouth, the construction of a barrage to exclude the salt water from the lakes, and the proposals for the construction of a navigable canal from Goolwa to Port Victor were adverted to. The navigation of the river is of a very intermittent character, and of late years there has been a marked diminution in the volume of trade entering South Australia. This is due to the fact that owing to the drought the rivers have remained unnavigable for long periods, also to the extension of railways. The differential railway rates of New South Wales, Victoria, and even South Australia, have had a marked effect on the river-borne traffic. At the present time the three States compete by great reductions in the freight of river-grown products. It was pointed out that wool grown on the Darling and conveyed by steamer to Echuca, is then carried to Melbourne by rail for 2s. 3d. per bale, whereas the charge to the settlers in the neighbourhood of Echuca is 6s. 6d. per bale. The charge for carrying sugar from Melbourne, if consigned to the Darling country, is only 11s. per ton, whereas the storekeeper in Echuca has to pay freight at the rate of 50s. for the same class of goods. The same thing applies to the South Australian railways, and upper river goods sent from Morgan and Murray Bridge are conveyed to Adelaide at a great reduction compared with local-grown products.

Dealing with the question of irrigation, the works constructed in Victoria on the Goulburn, Campaspe, Loddon, Wimmera, and Avoca rivers were described. The activity displayed by our Victorian friends in connection with the

conservation and distribution of the waters of the Murray basin is in striking contrast to the policy adopted in New South Wales. We have been collecting data in this State for a number of years, but to see the practical side of irrigation in the Commonwealth one must turn to Victoria. About 2,640,000 acres are commanded by water works, and Irrigation Trust channels, of which 276,000 acres are irrigated. The Mildura settlement is an object lesson of what can be accomplished in the arid districts of Australia. The land before irrigation, was practically valueless, whereas a population of 4,000 persons are now maintained on the products of 9,000 acres of irrigated culture. The Renmark Irrigation Colony in South Australia is another striking example of what the arid lands are capable of producing.

The Waranga reservoir on the Goulburn river now in course of construction, the proposed reservoirs at Barren Jack on the Murrumbidgee, at Cumberoona on the Murray, and at Wyangala on the Lachlan were described. The lecturer dealt with the importance of stream gauging, and gave details of the fluctuation of flow in the Australian rivers.

The Premiers' agreement, and also its subsequent modification respecting the division of the waters of the Murray Basin among the States of New South Wales, Victoria, and South Australia was explained. The lecture was illustrated by numerous lime light views, showing the various points of interest on the rivers, the class of boats trading thereon, and the weirs that have been connstructed in the irrigation areas of Victoria.

WATER CONSERVATION AND IRRIGATION—DISCUSSION.

Mr. McColl, M.H.R., Victoria, in addressing the Conference, said, he came over from Melbourne as a learner and not as a teacher, and felt some difficulty in addressing such an audience that night. He also desired to remind them that he was not a scientific man nor an expert, but for the last seventeen years he had represented the greater part of Victoria which was under irrigation, and had been associated with it from its earliest inception. He had been disappointed with the numerous mistakes which had been made and rejoiced over the successes which were not to be despised.

Arid countries, such as the north of Africa, the south of Europe, Palestine, and Egypt had prospered in past years because they used the water as it flowed from the hills to the fullest extent, and fell as they neglected the question of irrigation. He hoped the authorities would heed the lessons both of the past and present. He thought that in Australia there could not be an ideal system of irrigation owing to the absence of big mountain ranges, but the amount of water that was allowed to run to waste was most culpable. Around the coast there was a rainfall of from twenty to thirty inches, and next to nothing in the interior. In Victoria they had a mountain range running for a great part of the length of it. From that range there flowed down nine rivers. These rivers were allowed to flow to the sea to the extent of some 250,000 millions of cubic feet per annum, and the water which went to waste would cover four million acres twelve inches deep, was it not culpable on the part of the authorities to let such

volumes of water, with all its potentialities of wealth and progress run to waste.

In Victoria they had spent nine million pounds altogether on water conservation, storage, and irrigation, and people were running down irrigation and spoke as though they were under the impression that most of the losses in Victoria were due to irrigation. But the writing off that had been done there included relief to local bodies, mining communities, as well as country districts, and only a moiety applied to irrigation. But though the expenditure on water had not paid interest directly, the indirect benefit to the State far more than compensated for the outlay.

In the country districts, a system of Trusts have been established of two kinds, one for domestic and stock supply and the other for irrigation. The first were called Water Works Trusts, the latter Water Supply and Irrigation Trusts. The first included Urban Trusts and Rural Trusts, and they did not deal with irrigation though a little might be done from them, but were intended for State and domestic purposes only. The Water Works Trusts were initiated by the local municipal bodies by petition, which was open for inspection for a certain time, and if no objections were lodged the scheme went on. In some cases the municipal body controlled the administration, in others commissioners elected under the act did so. While in the Rural Trusts a large sum had to be written down, the Urban on the whole had paid their way fairly well. The procedure for constituting an Irrigation Trust was different. In this a petition to the Governor was prepared signed by half the land owners in the proposed district. In this petition the scheme of works was set out: the area and description of the land, the sources and quantity of water to be supplied, the proposed extent of rating, the estimated cost of the scheme, and the anticipated charges required for main-

tainance and management, also for payment of interest, with all other particulars of the scheme. This was formulated by the Trust's engineer, and sent to the Water Supply Department. The matter was then referred to the department's engineers who went thoroughly into all the calculations and statements made, and submitted their report to Chief Engineer of Water Supply; after criticism by him the petition and reports were referred back to the promoters of the Trust, for consideration of the various amendments made and charges proposed.

When the views of the trust and the department were brought to agree, a second petition, which requires to be signed by more than half the owners of land owning more than half the land in the proposed trust area was prepared and signed. The first petition did not bind any one, but the second petition made them liable for the cost of the works, and on it being sent in the trust was constituted and the works commenced. For the first few years no interest was charged, after that interest at the rate of $3\frac{1}{2}\%$ and $1\frac{1}{2}\%$ sinking fund was charged. The difference between a domestic and stock supply and an irrigation supply was that the former meant mere existence, while the latter comfort and competency. They could not have settled the country nor developed the enormous mining fields without it. In the Coleban Scheme there was a loss of nearly a million pounds, but without it there would have been no Bendigo mines to day. In Bendigo they had turned out an average of four thousand ounces of gold per week for fifty years, and for that period had yielded forty million pounds worth of gold which was an enormous recoup for expenditure on water. Bendigo was yielding now and to all appearances would continue to yield for generations to come. For the last nineteen years a continuous system of gauging the Victorian streams has been going on. The

system, he thought, was fairly perfect. In the cities and towns the charges for the water was by so much in the £ on the municipal value to a certain amount and after that by meter, at the rate of 1/- per thousand gallons.

The Victorian irrigation channels were on the semi-surface principle, the banks being formed from trenches so that the water was above the surface of the land to be irrigated and allowed of a gravitation supply. Some years ago it was found that the Trusts could not meet the interest, so Parliament took the matter in hand and wiped off a portion of the liability, as I have told you previously. The liability for the Trust works ran from 12/- to 30/- per acre, and under the new order of things since the writing off, the Trusts have to meet their engagements and the rates struck amounted from 1/- to 4/- in the £ on the municipal assessment, with a charge of from 6d. to 1/- per inch per acre for water supplied. They heard a good deal of the non-success of Trusts in Victoria, but the people were not so much to blame, the reason being the want of the necessary conservation of water and inability to regulate the flow of the streams, so as to retain the winter supplies for use in the dry seasons. After the boom there came a very bad time in Victoria. Money was scarce and a new Government came in not in touch with irrigation; the Trusts for these reasons were not the success they ought to have been. Irrigation was new, and a very great many mistakes were made; sometimes in the use of too much water, and sometimes through want of knowledge of the soil. The engineers as well as the people have all to learn and know irrigation was not the success so far in Victoria it was anticipated, but it would be yet.

It was a great pity that in Victoria, and also in New South Wales, there was not a continuity of policy in large questions. In these great and important matters one of

the reasons why we have not had the success in Victoria was due to the many changes of Government. It was, however, spreading, and in the case of the Rodney Irrigation Trust they were using twelve to thirteen times as much water as they did 12 years ago. As irrigation was increasing so was production spreading the same way. Irrigation has been the means of keeping the people on the land, and where the Trusts had not been altogether a success, it had kept homes together in districts which would otherwise have become depopulated.

To show the difference between watered and dry districts to the west of Echuca there were nine parishes without water supply. Twenty years ago there were seven hundred land owners, and to-day only one hundred and ten; about twelve miles east of Echuca the Rodney Trust was constituted about twelve years ago, and there population has largely increased, while production and values increased fourfold. Yet both districts had similar land and facilities, the only difference being one had used the water the other did not. The people were now becoming seized of the value of water and they knew now what quantity of water to put on and how to use it. In one case a man had a dry selection of 320 acres, with a stock of sixty cows, which were only yielding him fifty gallons of milk per day. He removed them to another selection containing 320 acres, the result being that the yield doubled in one week, and in three weeks was four times as much, just through changing from a dry paddock to a wet one.

The allocation of cost of irrigation works was a complex problem, and one of the difficulties was to decide what proportion should be borne by the State and what by the individual on the land. It was not fair that the whole liability should be thrown on those who had to use the water, because after the construction of storage works,

main channels, etc., from £1 to £2 per acre would probably have to be spent in distributories and preparing the land for irrigation. In the works on our coastal rivers and in our harbours we never dream of putting the cost of these works upon the people of these particular districts, and why should it be done to the full extent in the interior. The application of water in an arid district will increase production tenfold to what it was before, therefore, the State gains by the increase of wealth, railway freights, income tax and many other ways. The expenditure of money on water conservation and irrigation was not like turning over sand or cutting down scrub, such as the unemployed were put to, it brought increased employment and prosperity for all time to come.

The question of irrigation was not only a country question but a question for the city as well. We are all in the one boat, and one portion of the State could not suffer without the other suffering as well, and one part could not prosper without the rest sharing. The drought at Broken Hill was the means of almost closing up the Dapto works; a palpable object lesson for them he thought.

With regard to the agreement entered into at the recent Premiers' Conference on the subject of the Murray River, he hoped that the Parliaments of New South Wales and Victoria would not see fit to ratify the agreement which would, be disastrous to both States. He trusted the agreement would be looked into, and that they would get a proper settlement of the question of the Murray waters on a comprehensive basis, which would have to come some day and which would be better for all parties.

J. HAYDON CARDEW.—In addressing the meeting on the important question of water conservation and irrigation I had intended to deal with the economic aspect of the subject, because prior to Mr. McColl's address it has not been alluded to, but as that speaker has gone very fully into the

cost of construction and management of irrigation works in Victoria and has given us a splendid amount of information which is just as applicable to New South Wales there remains very little necessity for me to allude further to that aspect of the question, but there are other points upon which I should like to make a few remarks. The trouble has been that the people in Victoria went ahead too fast, and started constructing irrigation channels to distribute the water before it had been conserved, whilst in New South Wales they had proceeded too slowly. In a matter of this kind a certain amount of caution is necessary, because the financial prospects are very difficult to forecast and the undertaking is a new one in the experience of the people, but the time for enquiry and examination has long since gone by and the time for action has come.

It is now 18 years since the first Royal Commission was appointed to enquire into water conservation and irrigation, and ever since that report was obtained there has been a branch of the Public Works Department making surveys and developing schemes but with no result, and quite lately the Government imported Colonel Home, a distinguished irrigation engineer from India to make a further report, which has been received and carefully pigeon-holed. This report was considered to be a damper on the prospects of irrigation, but I regard it only as the expression of a cautious man who saw the difficulty of introducing too hurriedly a change in the methods of a very conservative people. As no allusion has been made to the report I will quote a few extracts, which I think are extremely pertinent to the present discussion.

"In connection with the financial prospects of irrigation projects it may be mentioned that the development of irrigation is a comparatively slow process, and that it is not reasonable to expect that a canal should pay as soon

as it is completed. This is fully recognised in India, where a canal is classed as remunerative, and carried out with borrowed money, if the forecast statements show that it will pay maintenance and interest charges within ten years after completion, and at the end of twenty years will pay the prescribed rate of interest on the sum at charge of project, which is the capital cost plus the balance, if any, of maintenance and interest charges over receipts from revenue.

"If the prospects of the Murrumbidgee canal should be considered sufficiently promising to warrant its being undertaken, it would appear desirable to allow the irrigation to develop itself before taking up the investigation of the Murray canal project. The experience gained on the older canal would be of the greatest value in preparing the project for the new canal, and in judging of its financial prospects, and it is quite possible that one canal will be found sufficient to meet the requirements of the colony for some years to come. Irrigation is a new industry here, and a little caution in expanding it can do no harm, and may save a good deal of money and trouble.

"The only irrigation works at present in hand are those at Hay, on the Murrumbidgee River, and at Wentworth, on the Murray, where provision is being made for pumping water from the rivers to irrigate land in the neighbourhood of the townships. There appears to be a fair prospect of these works proving successful, and if this should be the case, it is hoped that works of a similar kind may be carried out at the towns (such as Balranald, on the Murrumbidgee River) where there is a permanent supply of water and other conditions are favourable; such works should help to popularise irrigation and to introduce improved methods of cultivation, if only a market can be found for the produce."

The extracts I have quoted are clearly a warning to us to go slowly. In the semi-arid regions such as the greater part of this State, the settler only requires the water now and again for ordinary pastoral or farming purposes, and it would be very difficult to make the works pay under existing conditions, but if the settler were made to pay for the water every year, he would be compelled to make full use of it by altering his methods, and the only way to accomplish that would be by levying a rate on the assessed value of the property or making a charge at so much per acre; the result would be that a higher system of culture would be adopted and a closer settlement of the country.

If we do not get water conservation and irrigation works carried out in the near future, not only can we never hope to increase the population of the interior, but we cannot even retain the population that is there now. I think the time has arrived for definite action to be taken and for the settlers on the land to act for themselves and prove their self reliance and ability without leaning on the Government. The object of the Royal Society in getting these papers read was to ventilate the subject and to educate the public up to the great necessity for some action being taken by carrying out the object lesson suggested by Colonel Home at the same time bearing in mind the motto "*Festina lente.*"

INDEX.